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ELEMENTS
OF
CHEMISTRY
AND
NATURAL HISTORY.

TO WHICH IS PREFIXED,

THE PHILOSOPHY OF CHEMISTRY.

BY A. F. FOURCROY.

FIFTH EDITION,
WITH NOTES,
BY JOHN THOMSON, SURGEON, EDINBURGH.

IN THREE VOLUMES.

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TO

JAMES RUSSEL, ESQ.

PRESIDENT OF THE ROYAL COLLEGE OF SURGEONS,
EDINBURGH.

SIR,

PERMIT me to inſcribe to you the following Edition of Fourcroy's Elements of Chemiſtry. In offering to you this ſmall mark of perſonal regard, I have been influenced not more by conſiderations of private friendſhip, than by my eſteem for your virtues, and my reſpect for your talents, knowledge, and profeſſional ſkill.

I am,

SIR,

Your moſt obedient ſervant,

JOHN THOMSON.

ADVERTISEMENT.

In publiſhing the following tranſlation of Fourcroy's Elements of Chemiſtry, I conſider myſelf as merely the Editor; for unleſs where alterations or additions have been introduced into the preſent edition, I have adhered rigidly to the tranſlation of Mr. Nicholſon. I was too well aware of the ſuperiority of this ſkilful chemiſt, and accurate tranſlator, to believe I could improve upon his labours, and I was unwilling to loſe the advantage of following ſo able a guide.

To this edition I have prefixed the Philoſophy of Chemiſtry by the ſame author; here alſo I have adopted an anonymous tranſlation, publiſhed by Johnſon of St. Paul's Churchyard. This excellent little treatiſe will form, I am convinced, an uſeful introduction to the large work.

In one inſtance only, and that a trifling one, have I ventured to alter the text. It is in the account which is given of Mr. Kirwan's Mineralogy. The ſecond edition of this work does not ſeem to have been known to Fourcroy; and I was deſirous to direct the attention of the young ſtudent to the moſt perfect ſyſtem of mineralogy which has yet appeared in the Engliſh language.

In compoſing the notes, I have had it chiefly in view to exhibit a ſhort abſtract of the moſt intereſting diſcoveries and improvements which have been made in the ſcience of chemiſtry within the period of the laſt twenty years, and to make accurate references, on every ſubject of importance, to the various original memoirs, eſſays, and writings, from which farther information may be derived. By intermixing in this manner the hiſtory of modern chemiſtry, with a work ſo long and ſo deſervedly popular, I have endeavoured to aſſiſt thoſe who may be deſirous to proſecute this intereſting ſcience beyond the narrow limits of an elementary treatiſe. How far I have ſucceeded in theſe objects is now, with much deference, ſubmitted to the judgment of an impartial public.

MINT CLOSE, EDINBURGH,
July 23. 1798.

JOHN THOMSON.

THE

AUTHOR'S PREFACE.

NO ſcience has ever been more generally purſued, or more attentively ſtudied, than chemiſtry has been, during the laſt twelve years; and never has any ſcience made ſuch rapid progreſs in ſo ſhort a period of time. From theſe two circumſtances, a fifth edition of this work has become neceſſary. The rapid ſale of the ſecond edition, which was almoſt entirely diſpoſed of in leſs than eighteen months, did not leave me ſo much time to beſtow upon the third edition, as I had to improve and to enlarge the firſt; the whole additions, therefore, made to the third edition did not amount to a ſingle volume, while two additional volumes have been given along with the ſecond. In the ſucceſſive editions of an elementary treatiſe, which men of ſcience, and an enlightened public, have ſanctioned with their approbation, there muſt indeed be a period when farther additions become improper, and when nothing remains but to review and correct it with care. To this ſtate my work was brought, in my own opinion, in the third edition. The new diſcoveries made after the year 1786 would have added little to the ſize of that edition, had I not, by the advice of ſome well informed friends, and in conſequence of obſerving the impreſſion which my work made upon beginners, thought it my duty to recompoſe and to enlarge ſeveral of the chapters in the hiſtory of ſaline ſubſtances, of ſome of the metals, and of ſeveral of the immediate principles of vegetable and animal bodies. In this fifth edition, the facts added to the third edition are by no means ſo numerous as thoſe formerly added to the ſecond; they occupy in all but a few pages; ſo that this edition, like the third, is compriſed in five volumes.

When in the year 1780 and 1781 I drew up an abſtract of the facts which then conſtituted the ſcience of chemiſtry, to ſerve as a ſyllabus to my lectures, I followed the arrangement which I had adopted in my lectures, and of which the experience of ſeveral years had taught me the advantages. The unexpected ſucceſs of that work determined me to follow the ſame plan in the ſecond edition, publiſhed about ſeven years ago. The continuance of the ſame favourable reception, by a learned and inquiſitive public, the preference which the rapid ſale and various tranſlations authoriſe me to ſay has been given to my elements in the ſtudy of chemiſtry, have impreſſed it on me as a duty not to change the general arrangement which was adopted in the firſt edition. To alter that arrangement, after having been ſo long accuſtomed to it, would be to form a new work. I will not deny, however, that it is now perhaps neceſſary to change this arrangement; the acquiſition of more correct knowledge, the introduction of juſter and more concluſive modes of reaſoning, and the numerous and accurate experiments with which chemiſtry has been enriched ſince the publication of the firſt edition, require that theſe elements ſhould be arranged on a plan ſomewhat different from that which I originally adopted. In this new arrangement, the hiſtory of all combuſtible ſubſtances, ſuch as ſulphur, carbon, metals, &c. ſhould be placed before that of acids or of ſalts, ſeveral of which are either bodies that have been burned, or compounds formed from combuſtible bodies. In this way we ſhould proceed from the ſimple to the compound; we ſhould not then ſeparate the acids of one kingdom from thoſe of the other two, and we ſhould reſerve for diſtinct chapters the differences which exiſt between the principles of organic bodies, and thoſe of minerals. I have exhibited a ſketch of this new elementary method, in my courſe of chemiſtry intended for ladies, and the pupils of the veterinary ſchool. But although this laſt plan of arrangement ought, in my opinion, to direct the train of our ideas in the ſtudy of chemiſtry, yet that which I have followed in the different editions of this work is not without its advantages. It requires indeed greater efforts of the mind; but even this is perhaps favourable to improvement. It exhibits the ſame facts under two different forms; it obliges the mind to reconſider the ſame phenomena in different lights, and to conceive more diſtinctly their mutual relations.

I may obſerve, that the theory laid down in the third edition of theſe elements, differed eſſentially from that in the two former. In them, I acted merely as the hiſtorian of the different opinions which had hitherto prevailed among chemiſts. In the third, though I did not entirely quit this character, and although I explained the principle theories which had been propoſed, yet I took a decided part, and adopted completely the doctrine which ſome philoſophers have called the *pneumatic* or *antiphlogiſtic*. In this fifth edition, my opinions are ſtill more ſtrongly expreſſed, becauſe my conviction of the truth of the pneumatic doctrine is more firmly eſtabliſhed. I hope that thoſe who ſhall ſtudy theſe elements attentively, and without prejudice, will find that this doctrine differs from all the chemical theories which have ſucceeded each other in framing no ſuppoſitions, in admitting no hypothetical principles, and in conſiſting merely in a ſimple relation of facts. I think I may venture to aſſert, that the philoſophers who have not yet entirely adopted this doctrine, and particularly thoſe who have oppoſed it with undue warmth, have not completely underſtood our opinions. They do not ſeem to be aware that the baſis of our opinions, the foundation upon which our principles reſt, is not to be compared with what has been termed theory in phyſics; that in our ſyſtem we do nothing but deduce obvious concluſions from a great variety of facts; that we admit nothing which has not been demonſtrated by experiment, and that as we reject every hypotheſis, it is impoſſible we can commit miſtakes ſimilar to thoſe into which the learned authors of different ſyſtems of phyſics have fallen. Either I am much deceived, as well as thoſe modern chemiſts to whom we owe ſo many ingenious diſcoveries, or the riſing generation who are now employed in ſtudying the ſciences will renounce, as we have done, thoſe hypotheſes which have been ſo long agitated in the ſchools, and confine themſelves entirely to the reſults of experiments.

The modern chemical theory which has been denominated the pneumatic, and from which phlogiſton has been entirely excluded, daily acquires new converts. It is now ſo generally admitted, that more than three fourths of thoſe who proſecute the ſtudy of chemiſtry, and particularly of thoſe who teach it, have adopted it. Two of the moſt diſtinguiſhed chemiſts in Europe, Dr. Black and Mr. Kirwan, after having examined the new doctrine of the French chemiſts with the greateſt care, and after having oppoſed it for ten years, have now adopted it with that candour ſo becoming men of true ſcience. "At length," ſays

Mr. Kirwan, in a letter to Berthollet, dated 26th January laſt, "I lay down my arms and abandon the "cauſe of phlogiſton. I ſee clearly that there is no "well atteſted experiment which proves the production of fixed air from pure inflammable air. This "being the caſe, it is impoſſible to prove the preſence "of phlogiſton in the metals, ſulphur, &c. Without "deciſive experiments, we cannot ſupport a doctrine "in oppoſition to well eſtabliſhed facts. I ſhall, myſelf, publiſh a refutation of my own eſſay on phlogiſton."

Dr. Black expreſſes himſelf in the following manner, in a letter to Lavoiſier: "You have heard, that "in my lectures I endeavour to explain to my pupils, the facts and principles of the new doctrine "which you have ſo fortunately diſcovered, and that "I begin to recommend it to them as being more "ſimple, more conſiſtent, and better ſupported by "facts than the old theory. And how could I do "otherwiſe? The numerous experiments which you "have made upon a great ſcale, and which you have "ſo happily contrived, have been conducted with "ſuch care and ſuch ſcrupulous attention to all the "circumſtances, that nothing can be more ſatisfactory than the proofs you have produced. The ſyſtem you have founded on theſe facts is ſo intimately connected with them, ſo ſimple and ſo eaſily underſtood, that it muſt every day be approved of "more and more, and will be adopted by a great "number of chemiſts who have long been accuſtomed to the old theory. You muſt not, however, expect to convince every perſon. You know well that "habit enſlaves the minds of moſt men, and makes "them believe and revere the groſſeſt abſurdities. I "muſt confeſs to you, that I have myſelf experienced

" its effects. Having been accuſtomed for the ſpace " of thirty years to believe and to teach the doctrine " of phlogiſton as it was generally underſtood before " the diſcovery of your ſyſtem, I long entertained a " diſlike to this ſyſtem which repreſents as abſurd a " doctrine which I had conſidered as fully eſtabliſhed. " This diſlike, however, which depended entirely on " the power of habit, has been gradually overcome by " the clearneſs of your demonſtrations and the ſolidity " of your plan. Although there be in every theory " ſome particular facts which it is difficult to explain, " yet I am convinced your ſyſtem is infinitely better " founded than the old, and cannot in this view ſuffer " by a compariſon. But though habit may prevent the " older chemiſts from adopting your ideas, the young " will not be influenced by the ſame cauſe; they will " all range themſelves under your ſtandard. We have " already experienced this in the Univerſity of Edinburgh, where the ſtudents are allowed the fulleſt liberty in the choice of their opinions in ſcience. In " general, they embrace your ſyſtem and begin to " uſe the new nomenclature."

It cannot then be ſaid that the antiphlogiſtic doctrine is not received, or that it has few partizans, ſince it has been adopted by the greateſt number of the moſt celebrated philoſophers and teachers of chemiſtry in Europe, ſince almoſt all thoſe of France teach it in their lectures, and ſince, in oppoſition to the twelve or fifteen chemiſts in Europe who continue to reject this doctrine, there are at leaſt fifty philoſophers and teachers of chemiſtry who make it the baſis of their writings and lectures. How, indeed, could a ſyſtem fail to ſtrike every ingenuous mind with its beauty and perſpicuity, which admits no hypotheſis, which exhibits only the reſult of fact, and which explains the greater part of the phenomena of nature and of art with a ſimplicity and eaſe unexampled in the older ſyſtems of phyſics? How could experiments ſo accurate, and repeated with ſuch care, and a mode of reaſoning ſo juſt, fail to produce conviction in impartial minds?

If we read without prejudice the hiſtory of modern chemiſtry, if we peruſe with ſtrict attention the writings and diſſertations publiſhed within the laſt ten years againſt the antiphlogiſtic doctrine, we ſhall ſoon perceive that the chemiſts who oppoſe this doctrine may be divided into two claſſes. One claſs does not underſtand the baſis of this doctrine, and appears to be even ignorant of the ſeries of experiments on which it is founded *. Such men it is in vain to oppoſe or

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* M. Baumé has publiſhed at the end of the new edition of his Elements of Pharmacy, an appendix, expreſsly intended to declare his oppoſition to the new doctrine, to deny the decompoſition of water, and to cry down the new nomenclature. He ſhows, unfortunately, in almoſt every line, that he does not underſtand the doctrine which he calumniates, that he has not repeated any of the accurate experiments on which it is founded, and that he is by no means well acquainted with the preſent ſtate of modern phyſics. Thoſe who remember the bad ſucceſs of the experiments and opinions of M. Baumé with regard to the converſion of ſilex into argil by fuſion with alkalis, the production of boracic acid from fat and clay, the ſpontaneous irreducibility of the *precipitate per ſe*, the preparation of ethers, of Starkey's ſoap, metallic ſalts with an exceſs of baſe, ſulphuric ſalts with an exceſs of acid, &c. &c. will be able to judge how far the works of ſuch authors deſerve to be refuted.

The ſingular objections to the pneumatic doctrine by Monnet, to whom this ſcience was ſo much indebted before the diſcovery of the gaſes, are, if poſſible, ſtill more aſtoniſhing. Without having, it would appear, ever ſtudied the modern chemiſtry, without having acquired a ſufficient knowledge of the new experiments and proceſſes which it exhibits, he animadverts with warmth, and even with acrimony, againſt Scheele, whoſe numerous and valuable diſcoveries have been confirmed by all the other chemiſts. In ſpeaking of the oxalic acid, the oxygenated muriatic acid, and the arſenical acid, he tells us that he has never ſeen them, that he has never been able to obtain them; he has the aſ-to attempt to convince. The long habit of making inaccurate and inconcluſive experiments in chemiſtry, and particularly the ſtrength of old opinions, totally incapacitate them for underſtanding any thing which is new. The other claſs, who ſeem to be influenced by the ſpirit of party, are more to be dreaded; they are acquainted with the experiments of the moderns, and ſay they have repeated them; they have themſelves made diſcoveries in the new chemiſtry; they attack the antiphlogiſtic doctrine with weapons in appearance more formidable than thoſe of the firſt claſs. They differ from the antiphlogiſtians only in their explanations and the mode of reaſoning they employ. Inſtead of going directly to their object, they follow a long and circuitous path. What proves that they are not in the true road to truth, is, that each phlogiſtian has framed a particular theory of his own, which has

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ſurance to ſay, that theſe acids do not exiſt, that all the pneumatic chemiſts are miſtaken, and that their ſyſtem is not tenable: Yet, in reading the diſſertation againſt the pneumatic chemiſtry, inſerted in the fourth volume of the Memoirs of the Academy of Turin, it will be eaſy to ſee that he has not underſtood the opinions of the modern chemiſts, that he has not comprehended the whole of their doctrine, and, what is worſe, that he has made no experiment with accuracy, and with the neceſſary precautions for obtaining thoſe reſults which he wiſhes to repel. In ſhort, with his manner of operating, and with his apparent contempt for the calculation of proportions in chemical analyſis, it was impoſſible for him to appreciate the value of modern diſcoveries; and he denies their exiſtence, becauſe he failed in repeating the experiments on which they are founded. We have only to requeſt thoſe who have ſtudied modern chemiſtry to read with attention the works which have juſt been quoted, and judge for themſelves of the ſtrength of the objections which theſe authors have propoſed. They will ſoon be convinced of the truth of our aſſertions, and will not fail to perceive why, in ſpite of ſo much oppoſition, the modern doctrine daily obtains new partiſans, and why it reckons among the number of its defenders three-fourths of the moſt diſtinguiſhed philoſophers in Europe. *Note of the Author.*

little or no relation to any other theory; ſo that there are now nearly as many theories, as many different kinds of phlogiſton, as there are defenders of phlogiſton.

The philoſophers who adopt the pneumatic theory are not only more numerous, but have beſides the advantage of agreeing among themſelves. This alone ought to weigh deciſively with thoſe who are entering upon the ſtudy of chemiſtry, if they are not yet qualified to decide for themſelves, nor to form an opinion from their own inveſtigation.

PREFACE

TO THE

PHILOSOPHY OF CHEMISTRY.

IN proportion to the advancement made by any ſcience, in proportion to the methodical arrangements it acquires to facilitate its progreſs, will its general truths be multiplied;—ſuch is the preſent ſtate of Chemiſtry. The principles of this ſcience have been created but a few years, and already is it rich in corollaries or general reſults, in which are included all its parts. A ſeries of theſe reſults may be highly uſeful. For twelve years I have been conſtantly employed in inveſtigating this ſeries; and I have often given a ſketch of it in my lectures, particularly in thoſe I deliver annually at the concluſion of my general and detailed courſe of Chemiſtry. While enumerating the phenomena that the known elaſtic fluids diſplay in their evolution, in their fixation, and in their influence on the operations of nature and art, I take occaſion to review all the fundamental truths of the ſcience; and from their ſurvey a picture is exhibited, which recals to the memory all the changes of which natural bodies are ſuſceptible in their reciprocal attractions. But in combining theſe capital truths, it is evident that great diſcernment is neceſſary to ſelect thoſe which are the moſt general, which comprehend all the *particular* facts, and from which they may be deduced as corollaries or immediate conſequences. It is neceſſary alſo that they be expreſſed clearly and accurately, without ambiguity, and without doubt; that their number be not too much increaſed, yet ſufficiently ſo as to include every fact of importance; and, laſtly, that they be arranged in ſuch an order, and follow one another in a ſeries ſo natural, as to exhibit the elements of the ſcience, and to diſplay its reciprocal relations and dependencies. Such are the ideas I had formed, and by which I have been guided in the inveſtigation of theſe truths. I conceived that they might ſerve to eſtabliſh a complete ſyſtem of Chemiſtry, which, fertile in its applications as well as in its principles, might recal to the adept all the facts which form the immenſe domain of chemical ſcience, and give to him who ſeeks information a competent idea of the career through which he has to run.

It appeared to me that, in order to accompliſh this object properly, it would not be ſufficient to exhibit a ſeries of uninterrupted propoſitions, without connection, and without coherence; but rather to unite them by general relations, in giving to them an arrangement which might enable the reader to diſcover and appreciate their connection, and, if I may uſe the expreſſion, their reciprocal reaction. This is what I term the Philoſophy of Chemiſtry. All the propoſitions of which it conſiſts have already been publiſhed in the chemical department of the Encyclopædia, under the article *Axioms.*

It might be uſeful, I conceived, to the lovers of this ſcience, to publiſh them ſeparately, and in a more convenient form. The ſucceſs attending the firſt edition of the Philoſophy of Chemiſtry has induced me to publiſh a ſecond. In it there are a few alterations and ſome ſlight corrections, with ſcarcely any additions. The nature of the work does not admit of them, unleſs the ſcience ſhall receive great acceſſions, and become enriched with new and important diſcoveries.

PHILOSOPHY OF CHEMISTRY.

ALL the facts and experiments of chemiſtry may be referred to the twelve following general phenomena:

1. The action of light.
2. The action of caloric.
3. The action of air in combuſtion.
4. The nature and action of water.
5. The nature and action of earths, and the formation of alkalis, with the parts they perform in combinations.
6. The nature and properties of combuſtible bodies.
7. The formation and decompoſition of acids.
8. The union of acids with earths and alkalis.
9. The oxydation and diſſolution of metals.
10. The nature and formation of vegetable ſubſtances.
11. The tranſition of vegetables to the ſtate of animal matter, and the nature of the latter.
12. Finally, the ſpontaneous decompoſition of vegetable and animal ſubſtances.

Theſe twelve heads may be conſidered as the titles of ſo many chapters, to each of which thoſe different articles of detail belong, that have a direct relation to the head, and which, all taken together, include the whole of the doctrines of chemiſtry.

CHAPTER I.

THE ACTION OF LIGHT.

I. LIGHT, whether it *come* from the ſun and fixed ſtars, or be diffuſed throughout ſpace, is modified in four different ways with regard to the bodies with which it comes into contact: Either it is reflected entirely from their ſurfaces to our eyes, and excites the ſenſation of whitenefs; or it is decompoſed, and ſome of its parts only are reflected, whence ariſe different colours; or it is more or leſs completely abſorbed, and produces blackneſs; or, laſtly, it paſſes through bodies, deviating more or leſs *from its courſe, by approaching the perpendicular*, and this conſtitutes tranſparency.

II. In its paſſage through tranſparent bodies, it experiences a refraction, the degree of which is in a direct ratio to the denſity of the body, if incombuſtible, but increaſing in proportion to the combuſtibility of the body through which it paſſes. Hence Newton divined the combuſtibility of the diamond, and the exiſtence of a combuſtible principle in water.

III. Light, in refracting, is decompoſed into ſeven rays; red, orange, yellow, green, blue, indigo, and violet. It has been ſuppoſed, that three of theſe colours, the red, yellow, and blue, were ſimple; and that the other four were formed each of the two contiguous to them; that is, the orange from the red and yellow, the green from the yellow and blue, the indigo from the blue and violet, and the violet from the red and indigo. But this ſuppoſition has never been proved. The decompoſition effected by means of the priſm, is a ſort of analyſis of light.

IV. Light alſo acts chemically on ſubſtances, occaſioning decompoſitions and combinations. This we infer from the difference exhibited by bodies immerſed in light, from the ſame deprived of this element. The former become in general coloured, volatile, and inflammable; the latter have the oppoſite qualities.

V. Thus, by the contact of light, ſome acids are decompoſed; many ſalts change their nature; the oxyds of metals in general re-approach the metallic ſtate: and vegetables acquire colour, and become ſapid and inflammable; deprived of light, they remain pale and inſipid, and are what we call *etiolated*.

VI. Theſe general effects are almoſt always owing to this circumſtance, that light deprives burnt bodies of the principle they abſorbed in burning, ſo that from incombuſtible, which they had become, they return to the combuſtible ſtate. It may be ſaid, that light generally *unburns* burnt ſubſtances.

Application of the preceding Propoſitions.

The colours of bodies.
Tranſparency.
Opacity.
Brilliancy.

Simple and double refraction.
Metallic luſtre.
The decompoſition of acids, and of metallic oxyds.
Decombuſtion.
The alteration of the colours of minerals.
Vegetation.
The decompoſition of water by the leaves of plants.
The renovation of the vital air of the atmoſphere.
The formation of oils.
The difference between the vegetables of hot climates, and thoſe of temperate ones, &c.

CHAPTER II.

THE ACTION OF CALORIC.

I. WHAT we call *heat* is a ſenſation produced by a ſubſtance to which modern chemiſts have given the appellation of *caloric.* When caloric is applied to our ſyſtem in a greater proportion than it already contains, the ſyſtem is warmed, and the ſenſation of heat produced. When, on the contrary, a ſubſtance of a lower temperature than our ſyſtem is applied to it, we feel the ſenſation of cold, becauſe we then loſe caloric.

II. Caloric penetrates all bodies; it ſeparates their particles by lodging between them, and diminiſhes their attraction; it dilates bodies, it liquifies ſolids, and rarifies liquids to ſuch a degree, as to render them inviſible, give them the form of air, and convert them into elaſtic, compreſſible, aeriform fluids. Hence it follows, that liquids are combinations of ſolids with caloric, and that gaſes are ſolutions of different bodies in caloric, which of itſelf is the moſt attenuate, ſubtile, light, and elaſtic of all natural ſubſtances; accordingly its weight cannot be eſtimated.

III. While caloric ſeparates the particles of bodies, and diminiſhes their attraction for each other, it proportionally augments their attraction for the particles of adjacent bodies. For this reaſon it is ſucceſsfully employed to produce combinations, and facilitate reciprocal unions. Hence the axiom, *corpora non agunt, niſi ſoluta*, bodies do not act, unleſs they be diſſolved.

IV. Every particular body differing from others both in the form of its particles and their ſeparation from each other, requires a different quantity of caloric to raiſe it to the ſame temperature; this is what is called *the capacity of bodies for caloric.* From this it follows, that different bodies, at the ſame temperature, or indicating the ſame degree of the thermometer, really contain different quantities of caloric.

V. This different quantity of caloric contained in bodies raiſed to the ſame temperature, which is with propriety termed *ſpecific* caloric, being incapable of being meaſured by the thermometer, a mode of aſcertaining it has been invented, by means of the quantity of ice which bodies at an equal temperature will diſſolve in deſcending to the ſame degree. The difference of the quantity diſſolved, gives the proportion of caloric contained in the ſeveral bodies, and the inſtrument employed to aſcertain this difference is called a *calorimeter.*

VI. All the experiments made by the modern philoſophers, who have inveſtigated the theory of caloric, prove, that bodies, in changing their ſtate, change alſo their capacity. We call change of ſtate in bodies, their becoming ſolid, liquid, or elaſtic fluid. Hence it follows, that by mixing two ſolid bodies at different temperatures, incapable of combining together, a mean of the two temperatures will be obtained, if their capacities be equal; but if their capacities be unequal, the temperature of the mixture will deviate more or leſs from the mean, and the difference will indicate the reciprocal capacities of the two bodies.

VII. The preceding phenomena ſhow, that caloric has different attractions, or different degrees of affinity for different bodies. In all combinations, therefore, this varying attraction of caloric ſhould be attentively calculated.

VIII. When bodies unite, either they loſe caloric, which indicates, that the new compound contains leſs than its component parts; and in this caſe the operation renders heat perceptible to our organs, and the temperature of the mixture is increaſed, which commonly takes place in our experiments: Or the bodies which combine abſorb caloric, and the new compound contains more heat than its component parts did ſeparately; and then, when the combination takes place, the mixture grows cold, the caloric, which was at liberty between its particles, unites with them more cloſely, and they even take ſome from contiguous bodies.

IX. Sometimes caloric adheres ſo forcibly to bodies, that it prevents their combining with others. Thus many diſſolved into gas, or elaſtic fluid, unite neither with other bodies, nor with one another, as long as they retain this ſtate of inviſible ſolution in caloric; ſo that recourſe muſt be had to double attractions to effect their combination.

X. The attraction of caloric for ſome ſubſtances, is ſo great, that it is very frequently employed with advantage for ſeparating theſe ſubſtances from the compounds into which they enter, and for analyſing or decompoſing compound bodies. This is what we do in diſtillation, and in all the decompoſitions effected by means of fire alone, or caloric, applied to very compound ſubſtances. The different elements of theſe compounds are gradually diſſolved in the order of their ſolubility in caloric, and ſeparated in the ſtate of vapour or gas.

XI. Light, applied at the ſame time with caloric, frequently aſſiſts its action, or has its action aſſiſted by it. Hence, tranſparent veſſels employed in furnaces are extremely uſeful to chemiſts, by tranſmitting light and caloric at the ſame time. A ſimilar effect is produced, by penetrating opake veſſels ſo thoroughly with caloric, as to make them red-hot, or render them permeable to light.

XII. There are bodies which abſorb caloric much more ſpeedily than others; this is called the property of *conducting caloric.* In general thoſe bodies which are moſt coloured are the beſt conductors. The cauſe of this phenomenon is unknown.

XIII. All theſe facts prove, that caloric is a particular ſubſtance, and not a modification of all ſubſtances, as ſome natural philoſophers have imagined; and it is far from having been ſhown to be the ſame thing with light; for the farther we advance in the ſcience of phyſics, the greater differences appear in the action of theſe two ſubſtances.

Application of the preceding Axioms.

The dilitation of ſolids, and the rarefaction of fluids.
Thermometers.
Fuſion.
Sublimation and volatilization.
The calorimeter, and tables of the ſpecific heat of bodies.
The changes of temperature in different mixtures.
Artificial refrigeration.
The production of gaſes, and their fixation.

Diſtillation at different temperatures.
Incandeſcence.
The different conductors of caloric.
The attractions of caloric.

CHAPTER III.

THE ACTION OF THE AIR.

I. The air acts in a collective maſs on all natural bodies, by its weight, moiſture or dryneſs, temperature, &c. Accordingly experiments of ſyntheſis or analyſis, made in contact with the air, differ conſiderably from thoſe which are performed in a vacuum, and it is always neceſſary to aſcertain the ſtate of the barometer, thermometer, and hygrometer, in chemical experiments.

II The atmoſphere is a vaſt laboratory, in which nature operates immenſe analyſes, ſolutions, precipitations, and combinations: It is a grand receiver, in which all the attenuated and volatilized productions of terreſtrial bodies are received, mingled, agitated, combined, and ſeparated. Conſidered in this view, the atmoſpheric air is a chaos, an indeterminate mixture of mineral vapours, vegetable and animal molecules, ſeeds, and eggs, which the luminous, caloric, and electric fluids are pervading and traverſing continually. The grand changes it experiences, and of which we are ſenſible in extenſive ſpaces by the appearance of water, light, free caloric, or noiſe, are called meteors.

III. Notwithſtanding this mixture, of which it ſeems impoſſible for us to aſcertain the nature, the atmoſpheric air is ſenſibly the ſame with regard to its intimate qualities, wherever we examine it; and it is decidedly marked by its two properties of ſupporting reſpiration and combuſtion. The cloſeſt analogy ſubſiſting between theſe two grand phenomena, from a careful ſtudy of what paſſes in combuſtion we may acquire a knowledge of the air.

IV. A combuſtible body cannot burn without the contact of atmoſpheric air, or a certain matter extracted from it. Thus combuſtion cannot take place in a vacuum.

V. A combuſtible body cannot burn in a given quantity of atmoſpheric air, beyond a certain period. A hundred parts of this air contain only twenty-ſeven capable of ſupporting combuſtion; when theſe twenty-ſeven parts have been abſorbed by the combuſtible body, the combuſtion ceaſes, as the other ſeventy-three parts cannot any way contribute to its ſupport. Hence it appears, that atmoſpheric air is a compound of two different ſubſtances, ſetting aſide a few matters foreign to it, which are mingled with it, but amount not to more than a hundredth part of its bulk. Of theſe two ſubſtances, one ſupports reſpiration and combuſtion: This is termed *vital air*; the other is the reverſe of it in both theſe reſpects, and is called *azotic gas*.

VI. Thus a body burning in the air effects a real analyſis of this fluid. It ſeparates from it and abſorbs the vital air, which augments the weight and changes the nature of the burning body. The azotic gas which remains is lighter than the atmoſpheric air, extinguiſhes bodies in combuſtion, and kills animals. It is alſo one of the conſtituent principles of ſeveral compounds, as we ſhall ſee farther on, particularly of ammoniac, or volatile alkali, the acid of nitre, and animal ſubſtances.

VII. A combuſtible body which has burnt in atmoſpheric air, and abſorbed all the vital air to which it is capable of uniting, can burn no longer in a freſh quantity of air: It has become incombuſtible, and frequently ſaline.

VIII. A body burning in atmoſpheric air never abſorbs completely the twenty-ſeven hundredth parts of vital air it contains. To make a perfect analyſis of the atmoſpheric air, and diveſt it entirely of this fluid, combuſtible bodies muſt be burnt in it repeated times.

IX. The portion of air thus abſorbed by combuſtible bodies, called above vital air, is alſo named *oxygen gas*. The former name is derived from its being the only elaſtic fluid capable of ſupporting life: The latter is given it, becauſe many bodies on abſorbing it are rendered acid.

X. Combuſtion then conſiſts in the fixation and abſorption of vital air by combuſtible bodies, and the decompoſition of the atmoſpheric air by theſe bodies. As the vital air only ſerves to ſupport combuſtion, it is eaſy to conceive, that a very combuſtible body, capable of abſorbing the whole of the vital air, may be employed to determine the proportion of the two atmoſpheric fluids: Thus phoſphorus is now uſed for the purpoſe of *eudiometry*, or to diſcover the purity of the atmoſphere, that is to ſay, the proportion of this vital air which it contains.

XI. As vital air is a gas, and many combuſtible bodies, when they abſorb it, render it fixed, and cauſe it to aſſume the ſolid form, the vital air, when it is thus precipitated, loſes the caloric, which held it in a ſtate of ſolution, and gave it the elaſtic fluid form: Hence the origin of the caloric diſengaged, or of the heat produced, during combuſtion.

XII. Combuſtible bodies differ from each other, firſt, In the rapidity with which they abſorb oxygen; 2dly, In the quantity of it they abſorb; 3dly, In the proportion of caloric which they diſengage from the oxygen abſorbed; and, by conſequence, 4thly, In the greater or leſs degree of ſolidity of the oxygen they contain after being burnt.

XIII. Burnt bodies, then, may be defined to be bodies combined with oxygen: Accordingly they are termed oxygenated, or oxydated ſubſtances: And as the greater number of known bodies are either combuſtible, or already burnt, we may be allowed to ſuſpect, that many incombuſtible natural bodies, with the compoſition of which we are unacquainted, are incombuſtible ſolely from being ſaturated with oxygen. With regard to ſome in this predicament, this conjecture has already been verified.

XIV. From ſeveral of the preceding axioms, it follows, that, when we burn a combuſtible body in order to procure heat, as we do to mitigate the rigours of winter, we obtain at leaſt the greater part of the caloric from the air itſelf, with which it was combined. We may even aſſert, that the colder the air, the more heat is derived from it; becauſe, when the atmoſphere is extremely cold, more air paſſes into the fire in a given bulk. Indeed, it is well known, that the fire in our grates is much more ſcorching, and burns much more briſkly, when the air ſuddenly becomes cold; and the art of increaſing combuſtion by means of condenſed air thrown from a pair of bellows on wood already heated, is founded on this principle.

XV. Combuſtion, then, is not confined to the decompoſition of atmoſpheric air by abſorbing one of its principles; for it alſo decompoſes the vital air, by abſorbing, fixing, and rendering more or leſs ſolid, in the combuſtible body, the oxygen, or baſe of the vital air, and diſengaging the ſolvent of this baſe, caloric, in greater or leſs quantity.

XVI. There is another intereſting phenomenon in combuſtion, which modern chemiſtry is able to explain: That of the diſengagement of light, or the production of flame. It is demonſtrated, that the greater part of the light which conſtitutes flame is contained in the vital air, of which it is one of the principles: For, 1ſt, Combuſtible bodies afford much more flame when they burn in vital air alone, than in atmoſpheric air: 2dly, There are combuſtible bodies which do not burn with flame except in vital air: 3dly, To diſengage the oxygen from bodies which contain it, and convert it into vital air, it is not ſufficient to diſſolve it in a greater or leſs quantity of caloric, but it is neceſſary at the ſame time to add light: 4thly, There are burnt bodies which loſe their oxygen on the contact of light alone: In this ſenſe we muſt underſtand the property of *unburning* and *decombuſtion*, mentioned as a characteriſtic of light in the firſt chapter.

XVII. Vital air, therefore, is to be conſidered as a compound of a ſolidifiable, ponderous, acidifying baſe, *oxygen*, diſſolved in two menſtrua, caloric, and light, which of themſelves are extremely attenuate, highly elaſtic, and deſtitute of aſſignable weight. Combuſtion conſiſts in a more or leſs complete precipitation of the oxygen of theſe two menſtrua.

XVIII. Thus, a combuſtible body, in burning, diſengages from vital air, not only caloric, but alſo light; and every combuſtible body diſengages a different quantity of light from the vital air, as it does of caloric. It is probable that there are combuſtible bodies which ſeparate from vital air more light than caloric, while others diſengage from it more caloric than light.

XIX. The oxygen fixed in burnt combuſtible bodies remains more or leſs deprived of light and caloric; and the denſity or ſolidity it acquires in the proceſs, is one of the cauſes to which is owing the greater or leſs facility experienced in ſeparating the oxygen from burnt bodies in the form of vital air. For this, ſome require more caloric than light; others more light than caloric.

XX. It is eaſy to perceive, after what has been ſaid, that to ſeparate the oxygen from a burnt body, is to perform an operation the reverſe of combuſtion. We have no word in our language to expreſs this operation. It would not be improper to ſay, that we *unburn*, that we *diſoxydate* the body: Hence the terms of *unburning* and *diſoxydation*.

XXI. Beſide the greater or leſs force with which oxygen is retained in combuſtible bodies, according to its being combined with them in a ſtate of greater or leſs ſolidity, and its having loſt a greater or leſs portion of its ſolvents, caloric and light; it adheres to them by its attraction, its particular affinity to each. A conſiderable number of theſe affinities of oxygen for different ſubſtances are already known, and the degrees of ſome of them have been aſcertained.

XXII. It is from the degrees of theſe affinities, that we are frequently enabled to transfer oxygen from a burnt body to a combuſtible one. In this proceſs a combuſtion takes place, ſo much the more imperceptibly, or tacitly as it were, according as the oxygen is more ſolid in the burnt body, and more ſimilar in denſity to the body which abſorbs it, or into which it paſſes. But this kind of combuſtion ſometimes takes place with a vivid heat and flame: which phenomena occur, whenever the body which is to receive the oxygen muſt contain it in a more ſolid form than that from which it is extracted. Thus iron, zinc, antimony, arſenic, &c. burn with flame, when heated with oxyd of mercury, from which they attract the oxygen, to contain it in a more ſolid form.

Applications of the preceding Propoſitions.

The obſtacle which air oppoſes to evaporation, the ebullition of liquids, ſublimation, &c.
The ſolution of water in air, and the hygrometrical ſtate of the atmoſphere.
The efloreſcence and deliqueſcence of ſaline bodies, &c.
Aqueous meteors.
Experiments made at different heights of the atmoſphere.
Experiments made in a vacuum.
The comparative nature of combuſtible bodies.
The increaſe of weight and change of nature in theſe bodies after combuſtion.
The hiſtory of native burnt bodies.
Artificial heat and flame.
The theory of furnaces.
The different eudiometrical proceſſes.
The reſpiration of different animals.
The mephitiſm occaſioned by combuſtion and reſpiration.
The diminution, increaſe, and ſupport of animal heat.
Tranſpiration from the ſkin and lungs, &c.

CHAPTER IV.

THE NATURE AND ACTION OF WATER.

I. WATER exiſts in three different ſtates: that of a ſolid, which is ice; that of a liquid, its moſt common form; and that of vapour, or gas.

II. Ice is a cryſtallization more or leſs regular, tranſparent, very ſapid, elaſtic, fuſible at a temperature above 32° of Fahrenheit's thermometer, and which ſuffers the eſcape of much caloric from its interior, in ſeveral combinations.

III. Ice at 32° abſorbs 112° of heat in melting, or ſuch a quantity of caloric as would raiſe a body of water of equal bulk with itſelf to 144°. Its capacity, therefore, is not the ſame with that of liquid water, which is owing to the difference of its ſtate, as has been ſaid in Chap. II. Sect. VI.

IV. Whenever liquid water loſes much caloric on entering into any combination, it ought to be conſidered as ſolid in it: Frequently it is even much more ſo than ice at 32°; whence ariſes the ſolidity of mortars, or cements, of which ſlaked lime form a part.

V. Water remains eternally ſolid on mountains, cooled for ages by the preſence of ice, and underneath the poles. In theſe places it forms a kind of rocks, or white concretions almoſt ſimilar to ſtones.

VI. Liquid water is pure, inſipid, deſtitute of ſmell, and 850 times heavier than air. It forms rivers, brooks, ponds, ſprings, rivulets, &c. It occupies the cavities, furrows, and, generally ſpeaking, the loweſt parts of the globe.

VII. It is very ſeldom pure, for it diſſolves, in the earth, and on its ſurface, air, ſaline gaſes, and terreſtrious ſalts: It acts even on the moſt ſolid ſtones, which it diſſolves, carries along in its courſe, depoſits, and cryſtallizes. Hence it has been named the grand ſolvent of nature. By it are produced various phenomena, and it is one of the moſt powerful agents, by which the ſurface of the globe is inceſſantly modified. Its motions, its currents, its action, have gradually changed the nature of minerals, and created a kind of new world on the face of the old.

VIII. Accordingly all the waters of the earth contain ſome ſubſtance or other, foreign to the nature of water; the preſence of which is diſcernible from the increaſe of their ſpecific gravity, their taſte, more or leſs flat, earthy, and crude, and the difficulty with which they boil, dreſs pulſe, or diſſolve ſoap. The more free any water is from theſe properties, which are repugnant to its eſſential character, the greater its purity.

IX. Water flowing in a ſandy channel, and expoſed to the open air, is ſufficiently pure for the purpoſes of life, and moſt of the uſes of the arts. On the contrary, that which traverſes chalk, gypſum, and marbles, or ſtagnates on turf, bitumen, and ores of metals, or in ſubterranean cavities far from the contact of the atmoſphere, is more or leſs impure.

X. The art of correcting hard or impure water by chemiſtry, conſiſts in expoſing it to the atmoſphere, agitating it in contact with the air, boiling it, diſtilling it, and afterwards combining it with air. Frequently the addition of aſhes, alkalis, or weak acids, ſerves to diminiſh the bad qualities of water; and ſometimes even completely removes them. Moſt adventitious ſubſtances, which diminiſh the purity of water, being either much more volatile, or much more fixed, than it, diſtillation is the moſt certain method of obtaining pure water. For this reaſon chemiſts always employ diſtilled water in their experiments.

XI. Liquid water, being a combination of ice at 32°, and ſuch a quantity of caloric as would have been ſufficient to raiſe the water to 144°, on the addition of caloric becomes rarefied: When it is raiſed to a temperature of 184°, it aſſumes the form of gas; it is vapour: In this ſtate it is far lighter than liquid water, it occupies a much more extenſive ſpace, it eaſily penetrates all bodies, it readily diſſolves in air, and its expanſive force from the increaſe of its temperature renders it capable of moving enormous weights.

XII. As liquid water abſorbs air, which renders it light, air alſo abſorbs and diſſolves water. This is the cauſe of water's evaporating. The ſolution of water in air is dry and inviſible as air itſelf: It is proportionate to the temperature of the atmoſphere. The hygrometer does not indicate with preciſion this water, for it is not affected by a complete ſolution of water in air, but moves according to the quantity of water which is juſt going to be diſſolved, and more eſpecially of that which is precipitating from it.

XIII. Water is not a ſimple ſubſtance, as had long been ſuppoſed. By burning with rapidity a number of combuſtible bodies, more or leſs heated, as charcoal and pit-coal already on fire, red-hot iron, zinc melted and red-hot, oil, &c., water is decompoſed, yielding to theſe combuſtible bodies the oxygen it contained.

XIV. In proportion as the oxygen of the water becomes fixed in the combuſtible bodies which it burns, its other principle capable of diſſolving in caloric forms the inflammable gas which is evolved. As this ſecond principle is one of the elements of water, it has been called *hydrogen*, and its elaſtic fluid ſolution in light and caloric, hydrogen gas. The diſengagement of this principle in the form of gas, which takes place wherever water is decompoſed by a combuſtible body, is the cauſe of a great number of detonations and fulminations.

XV. The hydrogen gas produced in various experiments always originates from water, either in conſequence of a preceding decompoſition, in which it had been combined in the ſtate of fixed hydrogen, with one of the ſubſtances employed, or from a decompoſition of water actually taking place in the experiments themſelves. All the inflammable gas, therefore, proceeds from water.

XIV. Reiterated experiments have proved, that water contains about 85 hundredth parts of oxygen and 15 of hydrogen. The recompoſition of water, one of the grandeſt diſcoveries of modern chemiſtry, confirms the analyſis of this body; for on uniting by combuſtion 85 parts of oxygen with 15 of hydrogen, a hundred parts of pure water are obtained.

XVII. When water is decompoſed by a combuſtible body, this is affected by means of a double affinity; that of the oxygen of the water for the combuſtible body, and that of its hydrogen for caloric. For this reaſon, the more caloric matter is employed in the experiment of decompoſing water by means of iron, charcoal, or the like, the ſooner is the water decompoſed. From this neceſſity for an extreme abundance of caloric in the operation, it is eaſy to conceive how the hydrogen, one of the elements of the water, acquires a levity ſo far beyond that of the fluid from which it is derived: In fact, while a cubic foot of water weighs ſeventy pounds, a cubic foot of pure hydrogen gas weighs only ſixty-one grains.

XVIII. Hydrogen gas, though always produced by the decompoſition of water, carries along with it various ſubſtances, either ſuſpended or diſſolved in it, according as the bodies from which it is extricated are more or leſs ſimple: Thus it is mingled with azotic gas, carbonic acid gas, or vital air; or it holds in ſolution, water, carbon, ſulphur, phoſphorus, arſenic, oil, alcohol, ether, &c. From the difference of theſe adventitious ſubſtances which it contains, it varies in ſmell, weight, and inflammability, the colour of the flame it yields, its action on different bodies, and alſo in the products diſtinct from pure water which it affords in burning. Hence are derived the ſeveral ſpecies and denominations of inflammable gas admitted by authors, of which hydrogen gas always conſtitutes the general baſis.

XIX. Hydrogen gas being one of thoſe natural ſubſtances that contain moſt caloric, it is among the number of combuſtible bodies, which give out moſt, and conſequently afford moſt heat in burning. Hence all compound combuſtible bodies, of which hydrogen conſtitutes the baſis, ſuch as oils, fats, and in general all that originate from organized bodies, yield, during the proceſs of burning, a conſiderable quantity of heat. Wood, oil, pit-coal, bitumen, alcohol, ether, and the like, are of this kind.

XX. It follows, alſo, from what has been ſaid, that thoſe compound combuſtible bodies, which contain much hydrogen in their compoſition, neceſſarily require a large portion of oxygen in burning, and afford water as a product of their combuſtion, in proportion to the quantity of hydrogen they contain. Thus a pound of alcohol, on being burnt, yields more than a pound of water, &c.

XXI. The combuſtible bodies which decompoſe water, generally ſpeaking, are thoſe which have a greater affinity, or ſtronger attraction, for oxygen, than hydrogen has: But this attraction is greatly aſſiſted by the preſence of caloric, which has a tendency to unite with the hydrogen. A large quantity of caloric can even occaſion the decompoſition of water by bodies which would be incapable of decompoſing it cold. To this light equally contributes.

XXII. The combuſtible bodies which will not decompoſe water at any temperature, in conſequence of their feeble attraction for oxygen, which in this caſe always remains inferior to that which ſubſiſts between oxygen and hydrogen, muſt, on the contrary, when they have been burnt by other means, be decompoſed, or ſuffer their oxygen to be taken from them, by hydrogen. This happens to the oxyds of lead, biſmuth, &c.

XXIII. Hitherto the art of chemiſtry has arrived at the knowledge of no means of decompoſing water, but by combuſtible ſubſtances, which take from it its oxygen: We are unacquainted with any capable of attracting its hydrogen, and ſetting its oxygen free. It would ſeem, however, that nature has inſtruments for effecting this inverſe manner of decompoſing water: The leaves of vegetables ſtruck by the rays of the ſun appear to decompoſe water by abſorbing its hydrogen, and diſengaging its oxygen in the form of vital air. This we may preſume to be in part the mechaniſm of vegetation, of the formation of oils, and of the renovation of the atmoſphere. See Chap. IX.

XXIV. While hydrogen and oxygen, each diſſolved into gas by caloric and light, remain in contact with each other cold, they do not combine; no inflammation occurs, no water is formed. But if the mixture be expoſed to an ignited body, ſtrongly compreſſed, or affected by any violent and forcible concuſſion, a combination of the two commences, combuſtion takes place, and water is produced.

XXV. A ſimilar phenomenon appears to take place in the atmoſphere. Atmoſpheric detonations, claps of thunder, ſeem to be nothing more than a combuſtion of hydrogen gas and vital air; and accordingly they are often ſucceeded by a torrent of rain. Some ſtorms of rain alſo appear to be in like manner owing to a ſudden formation of water in the atmoſphere, from the rapid combuſtion of hydrogen gas and vital air, occaſioned by an electric ſpark, ariſing from the neceſſary re-eſtabliſhment of an equilibrium of electricity between different clouds, or between the clouds and the earth.

XXVI. A multitude of chemical phenomena of nature and art, formerly inexplicable and ranked as miraculous, are now eſteemed the neceſſary conſequences of the decompoſition of water well underſtood. Of the truths exhibited in this chapter the influence on the general theory of chemiſtry is immenſe, as will appear in thoſe that ſucceeed.

Applications of the Propoſitions in this Chapter.

Artificial refrigerations.

The theory of the permanent ice covering the tops of mountains, and the neighbourhood of the poles.

The varieties of atmoſpheric and terreſtrial waters.

The art of correcting the bad qualities of waters.
The theory of the ebullition of water.
The difference between boiled water and water pregnant with air.
The diſtillation of water in the great, and that of ſalt water.
The theory of fogs and dew.
The theory of the hygrometer, and hygrometrical phenomena.
The burning of combuſtible ſubſtances by means of water.
The gaſes diſengaged from ſtagnant waters
The variety of inflammable gaſes.
The colouring of ſubſtances by inflammable gaſes.
The oxydation of metals, or ruſt, produced by damp air.
The theory of detonations.
Some phenomena of metallic ſolutions.
Some fundamental principles of the theory of vegetation, the formation of oils, &c.

CHAPTER V.

THE NATURE AND ACTION OF EARTHS AND ALKALIS.

I. WHAT was formerly called earth by way of eminence, and conſidered as an element, and the cauſe of ſolidity, dryneſs, inſipidity, indiſſolubility, &c., is now conſigned to that claſs of vague and indeterminate ideas, which the imagination, unſatisfied with the ſucceſs of experience, invented to ſupply the place of facts. At preſent no elementary earth is acknowledged; and inſtead of one earthy ſubſtance, we have at leaſt five, all of which have an equal claim to be denominated elements; for each enters into the compoſition of various bodies.

II. Of the five earthy ſubſtances that have been diſcovered, two are in ſome meaſure more earthy, dry, ſuſceptible of hardneſs, inſipid, &c.; while the other three poſſeſs ſaline properties, which render them ſomewhat akin to the ſubſtances denominated alkalis. Theſe three, which have in conſequence been termed ſalino-earthy, ſaline earths, alkaline earths, and earthy alkalis, are baryt, magneſia, and lime. The other two are ſilex and alumin.

III. The generical characters common to all theſe are dryneſs, unalterableneſs in the fire, infuſibility, and the quality of being inſuſceptible of decompoſition, and acting as ſimple and indeſtructible ſubſtances in combination. Beſide theſe, each has ſpecific characters by which it is diſtinguiſhed.

IV. Silex which has been named ſiliceous earth, quartzoſe earth, and vitrifiable earth, is rough to the touch; it ſcratches and wears away metals; it is infuſible, incombuſtible, inſoluble in water and moſt acids, ſoluble by alkalis in a ſtrong fire, and forming glaſs with theſe ſalts. It is found in abundance in ſand, quartz, flint, agate, jaſper, ſandſtone, and all ſtones that ſtrike fire, of which it conſtitutes the baſis. It has neither been analyſed, nor imitated by ſyntheſis. Some have conſidered it as the moſt ſimple of the earths, the terreous element, the origin of all the other earths; but experience has not ſupported their aſſertions. It is employed for various purpoſes, particularly for mill-ſtones, and making glaſs, cements, earthen-ware, &c.

V. Alumin, ſo named becauſe it conſtitutes the baſis of alum, the ſame which ſome authors have called argil, is ſoft to the touch, and adheſive to the tongue, it hardens in the fire, makes a paſte with water, unites with moſt acids, dries in flakes, acquires great hardneſs when mixed with water and ſilex, and is contained in a large proportion in clays, ſchiſts, ſteatites, &c. It is employed for various purpoſes of art, from its aptitude for moulding into different forms, and retaining them, and its qualities of hardening in the fire, and holding water. By ſome it has been erroneouſly conſidered as ſilex changed, attenuated, and rotted by the action of air and water, but with its intimate nature, or principles, we are totally unacquainted.

VI. Baryt, or *heavy earth*, is remarkable for its extreme ponderoſity. This is never found alone in nature, but always united with the ſulphuric or carbonic acid. In the fire, and in contact with the ſilex or alumin of the crucible, it aſſumes a blue or green colour: it is ſoluble in nine hundred times its weight of water, changes ſyrup of violets green, has a ſtronger affinity even than alkalis for moſt acids, and will any where detect the preſence of ſulphuric acid, and indicate its quantity. Its principles are unknown, though it is ſuſpected of being a metallic oxyd.

VII. Magneſia is very fine, very white, unalterable in the fire, ſoft, and light. It reſembles vegetable feculæ, requires near two thouſand parts of water to diſſolve it, very ſlightly greens the tincture of violets and mallow flowers, forms with acids extremely ſoluble ſalts, and is leſs retentive of acids than lime, which attracts them from it, having nearly the ſame affinity for them as ammoniac, with which and acids it forms ſalts with two baſes, or a claſs of triple ſalts. It exiſts in conſiderable quantity in ſerpentines, mica, ſlates, and amianthus; is equally incapable of analyſis with the preceding earths; and, like theirs, its compoſition is unknown.

VIII. Lime is the moſt alkaline of earths, and the only one that poſſeſſes an acrid, burning, almoſt cauſtic, diſagreeable, and urinous taſte. It is very powerful in converting the ſyrup of violets to a green colour; attracts water from the atmoſphere when ſlacked in it; heats greatly with water, and becomes ſolid with it; gives out a large quantity of caloric when ſlacked dry; diſſolves in leſs than ſeven hundred parts of water; attracts carbonic acid from the atmoſphere, and forms on the ſurface of its ſolution a pellicle of chalk, improperly called *cream of lime;* is unalterable alone, but melts with ſilex and alumin; and is formed of principles with which we are yet unacquainted, though it is evidently a compound.

IX. The pretended converſion of earths, each into other, admitted by natural philoſophers, is nothing more than a chimera: ſo far is it from being proved, that ſilex becomes alumin in conſequence of expoſure to the air, that flints are changed into chalk, and that chalk is converted into magneſia, as ſome have ſuppoſed on much too feeble grounds.

X. The three alkaline earths are to appearance more manifeſtly compound than the other two. There is reaſon to preſume, that azot is one of their principles, and gives them their alkaline properties: however, experience has yet afforded no proof in ſupport of this opinion; though their origin, aſcribed with conſiderable probability to marine animals, which contain a large portion of azot in their compoſition, renders it not deſtitute of foundation.

XI. As to the metallic nature of the five earths, which ſome ſuppoſed they had demonſtrated by an imaginary reduction of them into metals, by expoſing them to a violent heat in contact with charcoal; the very ſmall and few metallic globules obtained evidently came from the charcoal and the earth of the cupels, and has been diſcovered to be nothing more than phoſphur of iron, in the treatment of each of the different earths; whence it is ſufficiently proved, that they afford no metallic ſubſtance. Several natural philoſophers continue of opinion, that earths are ſpecies of burnt bodies, to which the oxygen is ſtrongly adherent, and incapable of being decompoſed on account of their powerful attraction for this principle; but in this they are not ſupported by experience.

XII. Earths combine by twos, threes, and even greater numbers, by proceſſes unknown to us, which nature employs on a very extenſive ſcale, to produce ſtones differing in hardneſs, texture, tranſparency, opacity, colour, form, &c. If art have failed to imitate theſe compounds, the reaſon is, time, ſpace, and quantity, are wanting. Something ſimilar to the natural earthy compounds, however, may be produced, by leaving a long time in contact, earths, intimately mingled, and moiſtened at firſt with a little water.

XIII. The three alkaline earths form a kind of intermediate link between earths and alkalis. The latter are diſtinguiſhable by their acrid, burning, and urinous taſte, their cauſticity, their ſingular action on the ſkin, and all animal ſubſtances, the quality of changing the blue colour of violets to a green, and even a greeniſh yellow, and deliqueſcency. We are acquainted with three ſpecies, potaſh, ſoda, and ammoniac. The firſt and ſecond have been called *fixed alkalis*, becauſe they melt and grow red in the fire before they become volatile; the third has been named *volatile alkali*, from poſſeſſing the oppoſite property.

XIV. Potaſh is known by the following characters:—It is dry, ſolid, white, chryſtalized in rhomboidal plates, fuſible at a temperature of 203°, and very deliqueſcent, abſorbs water with heat and a peculiar faint ſmell, combines with ſilex by fuſion, and forms with it a tranſparent compound. It is frequently found native with lime, and combined with different acids; but is chiefly obtained from vegetables, in the aſhes of which it remains after combuſtion. It is ſuppoſed that it bears ſome analogy to lime, and may perhaps be formed of azot combined with it: experience, however, gives no ſupport to this opinion.

XV. Soda is procured from marine plants by incineration, and conſtitutes the baſis of ſea-ſalt. It ſtrikingly reſembles potaſh in form, cauſticity, fuſibility, deliqueſcency, combination with ſilex by means of fuſion, action on ainmal ſubſtances, &c.; ſo that it was long confounded with it, and might have continued to be ſo, if it did not form very different ſalts with acids, and yield theſe acids to potaſh. It has been imagined, that ſoda was a compound of magneſia and azot, becauſe ſalts with ſoda for their baſe have been as frequently found with ſalts having for their baſe magneſia, as calcareous ſalts with thoſe having potaſh for their baſis: but both theſe opinions remain hitherto equally devoid of proof.

XVI. Ammoniac or *volatile alkali*, differs greatly from the two preceding ſpecies in its form of gas when diſſolved in caloric, in its liquid form when diſſolved in water, in its pungent and ſuffocating ſmell, its ſolubility in air, and its known and eaſy decompoſition by the electric ſpark, metallic oxyds, and the nitric and oxygenated muriatic acid. This decompoſition evinces, that ammoniac is a compound of hydrogen and azot; and for this reaſon it frequently exhibits the phenomena of a combuſtible ſubſtance. Hence alſo it is eaſy to concieve, how animal matters furniſh ammoniac in conſequence of putrefaction.

XVII. If azot ſhould at ſome future period appear to be the principle that forms alkalis, the atmoſphere will be found to conſiſt of a mixture of oxygen and alkaligen, each ſeparately diſſolved in caloric; and it will exhibit an immenſe reſervoir, from which the philoſopher will perceive nature drawing the materials of two claſſes of compounds, the moſt active and uſeful in a great number of her operations.

Applications of the Propoſitions in this Chapter.

The extraction, preparation, and purification of earths.
The theory of the arts of the potter, brickmaker, &c.
The theory of cements and mortars.
The reciprocal combinations of earths by means of fire.
The natural hiſtory of ſtones.
The compound nature of earths and ſtones.
The alteration of colours by means of alkalis.
Vitrification and the art of making glaſs.
The extraction and purification of potaſh and ſoda.
The theory of alkaline cauſtics.
Some points regarding putrefaction.

CHAPTER VI.

THE NATURE OF COMBUSTIBLE BODIES.

I. Combustible bodies are too various, numerous, and important in the phenomena they exhibit, and the combinations they are inceſſantly entering into with each other, and with the air, not to excite us to examine them with care, and endeavour accurately to aſcertain their properties and ſpecific characters.

II. In comprehending under this name all ſubſtances capable of combining more or leſs rapidly with oxygen, and diſengaging from it caloric and light, we ſhould arrange them in two claſſes; ſimple or indecompoſed combuſtibles, or ſuch as cannot be decompoſed, and combuſtibles more or leſs compound.

III. We call thoſe combuſtibles ſimple, which we are hitherto unable either to decompoſe, or to compoſe by the union of different ſubſtances. With their intimate nature we are unacquainted. Sometimes they occur ſingly in the mineral kingdom, or in one of the others; but they are found moſt uſually combined two and two together. Such are the diamond, hydrogen, ſulphur, phoſphorus, carbon, and the metals. Each of theſe ſix genera muſt be conſidered ſeparately.

IV. The diamond is the hardeſt of all the bodies that we know. It is very remarkable for the power with which it refracts and decompoſes light, from which Newton diſcovered, that it was very combuſtible. It is found native, cryſtallized in octaedra, dodecaedra, &c.; exhibits ſome varieties differing in texture, denſity, and colour; burns with a perceptible flame, and is converted into vapour by burning. Its combination with oxygen is unknown. Few ſubſtances act upon it; and, if it were not combuſtible, it might be conſidered as inſuſceptible of alteration. We know no compound into which it enters as a conſtituent part; and it ſeems of all bodies the leaſt obedient to chemical attraction.

V. Hydrogen is one of the principles of water. With caloric and light it forms hydrogen gas, ſixteen times as light as air, inſoluble in moſt ſubſtances, capable on the other hand of diſſolving ſulphur, phoſphorus, carbon, arſenic, oils, &c.; and thus forming the different ſpecies of inflammable gas, formerly called ſulphurated, phoſphorated, carbonated, arſeniated, oleaginous, &c. hydrogen gas. It decompoſes ſeveral metallic oxyds, and acids with ſimple and known radicals; imparts to all the compounds into which it enters, whether they be combuſtible or not, a conſiderable refringent power, which property led Newton to conjecture, that a combuſtible ſubſtance was contained in water; becomes fixed in organized bodies, and forms one of the principles of the mixed combuſtibles they contain. See Chapters IV. and X.

VI. Sulphur is a yellowiſh ſubſtance, odorate, electric, tranſparent and octaedral, opake and priſmatic, and fuſible. It is ſuſceptible of two kinds of combuſtion; the one ſlow, with a blue flame, and the formation of ſulphurous acid; the other rapid, with a white flame, during which ſulphuric acid is produced. It combines with earths and alkalis; becomes ſoluble when thus combined; unites with metals, and forms ſulphurous ores; and exiſts in the earth in very large quantity, either alone, or combined with metal.

VII. Phoſphorus is a white, tranſparent, cryſtallized, lamellated, and extremely fuſible ſubſtance. It burns in two modes; ſlowly, in every temperature with which we are acquainted, emitting a white flame and acrid odour, and forming phoſphorous acid; rapidly, in a temperature of 147°, with a vivid and very brilliant flame, without any perceptible odour, and forming phoſphoric acid. It is never to be found pure in a native ſtate, on account of its extreme combuſtibility; unites with ſulphur, and with metals; is ſoluble in hydrogen gas; takes away oxygen from ſeveral metals, and ſeparates them from acids, reſtoring their proper form and metallic luſtre; and exiſts more abundantly in the mineral kingdom, even than in the animal, to which it was once excluſively attributed.

VIII. Carbon is the combuſtible matter of coals, ſuppoſed pure and iſolated from earths, alkalis, ſalts, &c. It is combuſtible in a great degree of heat; forms carbonic acid when united with oxygen; has the ſtrongeſt attraction for oxygen of any known ſubſtance, and deprives all other burnt bodies of this principle; exiſts in abundance in animals and vegetables, conſtituting almoſt wholly the ſolid baſis of the latter, and on that account remaining, and preſerving their form, after they are decompoſed, either ſpontaneouſly or by the action of caloric; is ſoluble in alkalis, and hydrogen gas; unites with metals, forming with iron, in particular, ſteel, and carbure of iron, improperly called *plumbago*, *lead ore*, or *black lead;* and is found in each of the natural kingdoms.

IX. Metals are well known for their great ponderoſity and luſtre: they are fuſible, cryſtallizable, and combuſtible; decompoſe water and ſeveral acids; unite with ſulphur, phoſphorus, carbon, and each other, at different temperatures; and in their ſtate of oxyds, perform a double function, that of acids with earths and alkalis, and that of ſalifiable baſes with acids. This genus differs from all that precede, particularly in the number of its ſpecies. To give a juſt idea of theſe, of which there are ſeventeen with which we are well acquainted, and this number will probably be ſtill farther increaſed by new reſearches, I ſhall divide this genus into five ſections: In the firſt, I ſhall compriſe brittle and acidifiable metals, of which there are three, arſenic, tungſten, and molybdæna: In the ſecond I ſhall rank thoſe which are brittle, and ſimply capable of oxydation, of which I reckon five ſpecies, cobalt, biſmuth, nickle, manganeſe, and antimony: The third ſection will include the ſemi-ductile and oxydable, of which there are two, zinc and mercury: The fourth ſection will be aſſigned to ſuch metals as are perfectly ductile, and eaſily oxydable which are tin, lead, iron, and copper: And the fifth will comprehend thoſe that are perfectly ductile, but oxydable with difficulty, which are ſilver, gold, and platina. As the ninth chapter is reſerved for the moſt important chemical properties of metals, it will be ſufficient here to exhibit briefly ſome ſpecific differences of each of theſe bodies; obſerving, that the appellations of *ſemi-metals*, *imperfect metals*, *and perfect metals*, manifeſtly originating from the erroneous ideas of alchemy, ought to be diſcarded from the language of a ſcience that has any pretenſion to accuracy.

A. Arſenic is lamellated, of a bluiſh gray colour, brilliant and fragile; and burns with a blue flame, and a ſmell reſembling that of garlic.

B. Tungſten is of a gray white colour, granulated, friable, almoſt infuſible, and ſcarcely ſoluble in acids, though extremely oxydable and acidifiable by the operation of air and caloric.

C. Molybdæna is in the ſtate of powder, or grains, blackiſh, ſhining, agglutinated, fragile, very little fuſible, and by burning becomes a white, volatile, priſmatic, and acidifiable oxyd.

D. Cobalt is granulous, fine, of a roſy white colour, fragile, pulverable, difficult of fuſion, and becomes blue when melted with glaſs.

E. Biſmuth is in large laminæ, of a yellowiſh white, brittle, eaſily fuſible, very cryſtallizable, and extremely oxydable.

F. Nickel is gray, granulous, hard, a little fragile, extremely difficult to fuſe, and affords a green oxyd by means of caloric and air.

G. Manganeſe is of a gray white colour, and fine grain, brittle, very difficult to fuſe, and of all metals the moſt combuſtible in the air alone, ſo that it changes colour immediately on expoſure to it, and is reduced to a black duſt in the courſe of a few days. It ſhould be kept underneath alcohol, or oil, to prevent it from burning.

H. Antimony is of a pure white, in large laminæ, brittle, hard to fuſe, and ſublimes on combuſtion in the air into a white, cryſtallized oxyd, which almoſt acts the part of an acid in uniting with alkalis.

I. Zinc is of a blue white colour, in large laminæ, ſemi-fragile, in ſome degree malleable, eaſy to fuſe, the moſt inflammable of metals, burning, when red hot, with a beautiful yellowiſh white flame, and powerfully decompoſing water.

K. Mercury is fuſible at 30° below 0 of Reaumur's thermometer, and congeals at 31°, becomes a black oxyd (*æthiops per ſe*) by mere diviſion, or is extinguiſhed by this ſimple proceſs in every viſcous or conſiſtent matter with which it is triturated.

L. Tin is of a brilliant white colour, ſoft, light, little ſonorous, capable of being ſcratched by the nail, very fuſible, very combuſtible, and affords a white oxyd, which deſtroys the tranſparency of glaſs, and converts it into enamel.

M. Lead is of a dull bluiſh colour, heavy, ſoft, extremely fuſible, and affords an oxyd the moſt vitrifiable of all we know, and a glaſs of a yellow hue, reſembling that of a topaz.

N. Iron is white, fibrous, the moſt tenacious of metals, very difficult to fuſe, very combuſtible, and the only metal attracted by the magnet. It readily decompoſes water, changes to a powder in the air, unites with carbon, which converts it into ſteel, and is the only metal any way abundant in the two organic kingdoms.

O. Copper is of a fine ſhining red, very ſoft and ductile, odorate, and poiſonous. It burns with a green flame, and affords brown, blue, and green oxyds, the laſt of which is formed in damp air.

P. Silver is of a pure and brilliant white, deſtitute of ſmell and taſte, very ductile, not oxydable by caloric and air, burning with a greeniſh flame by the electric ſhock, growing black from the fumes of ſulphur, unalterable by the air alone.

Q. Gold is of a fine brilliant yellow, extremely ductile, leſs combuſtible and leſs oxydable than ſilver, and even ſtill leſs alterable than it by the contact of air. It is convertible into a fine purple oxyd by the electric ſhock.

R. Platina is the heavieſt, moſt infuſible, leaſt combuſtible, and leaſt alterable of all metals. It is of a gray white colour, poſſeſſes little brillancy, and will at ſome future period become one of the moſt valuable inſtruments of the arts.

X. Compound combuſtible bodies are all ſuch as reſult from a combination of ſome of the preceding ones: thus the ſolutions of ſulphur, carbon, phoſphorus, and arſenic, in hydrogen gas, are compound inflammable gaſes: and the combinations of ſulphur with phoſphorus, of carbon with iron, of different metals with ſulphur, phoſphorus, and each other, are compound bodies. Such are almoſt all the combuſtibles we meet with in nature: it is the province of art to ſeparate them from each other, and exhibit them pure and iſolated.

XI. When we compare the properties of compound combuſtible bodies with thoſe of ſimple combuſtibles, we perceive, that the former ſometimes abſorb oxygen with more avidity than if they were alone, as many metallic ſulphures, and alloys; at other times, on the contrary, we find them leſs ready to burn, on account of the ſtrong attraction they poſſeſs for each other, which is the caſe in general with phoſphorated metals. There are even ſome that are long unalterable in the air, appearing to have loſt by their intimate combination the property of being combuſtible, which they exert only when ſtrongly heated; as the carbure of iron, which is even employed with ſome ſucceſs to prevent iron from contracting ruſt.

XII. Hydrogen and carbon, very intimately united together in the capillary tubes of vegetables, and frequently containing ſmall portions of earths, alkalis, acids, and eſpecially oxygen, form bitumens, oils, and reſins, which, though they have a tendency to burn and ſeparate, preſerve ſome time the equilibrium, of their combination, till a rapid increaſe of temperature, accompanied with the contact of air or water, puts an end to this equilibrium, by iſolating their elements, and uniting them ſeparately with oxygen. Accordingly the products of theſe compound combuſtibles are univerſally water and carbonic acid. It is the ſame with alcohol, and with ether, formed by modifications of the principles of vegetable matter, which, in their ultimate analyſis, are nothing elſe than combinations of hydrogen and carbon with more or leſs oxygen and water. See Chapters X, XI, XII.

XIII. This exhibition of the different ſpecies of combuſtible bodies, and their principal characteriſtic properties, ſhows the part they act in the phenomena of the globe. It authoriſes us to divide almoſt all the productions of nature into two grand claſſes, one of combuſtible bodies, the other of bodies already burnt: In the maſſes and action of the former we diſcern the cauſes of inflammable meteors, partial heat, volcanoes, the perpetual alterations of the ſurface of the earth, &c.; in the exiſtence of the latter, we perceive the ſource of the number and diverſity of acids, ſaline compounds, oxyds, and metallic ſalts, which vary in a thouſand ways the appearance of ores, their reciprocal decompoſition, and their alterations by the action of water, air, and light; in fine, we diſcover in vegetables machines which nature has organized for the purpoſe of intimately combining ſeveral of theſe ſubſtances with each other, in order to form compounds more ſubſervient to its grand deſigns, as they are leſs durable and permanent.

Applications of the Propoſitions in this Chapter.

The circumſtantial hiſtory of the combuſtion of each combuſtible ſubſtance in particular.

The hiſtory of ſoils impregnated with ſulphur, and of native ſulphuric acid.

The phenomena of natural inflammable gaſes in quarries, mines, the atmoſphere, &c.

The properties of earthy, alkaline, and metallic ſulphures.

The converſion of ſulphures into ſulphits and ſulphats by the action of air and water.

The properties, extraction, and combinations of phoſphorus: Metallic phoſphures.

The exiſtence of native metallic carbures.
The phenomena depending on the denſity, weight, ductility, and fuſibility of metals.
The properties and uſes of alloys.
The formation of ſecondary ores, from native metallic ſalts.
Volcanoes, and ſulphurous and thermal waters.
Bitumens; the compariſon of ſulphur, carbon and ſimple combuſtible bodies, with oils, &c. &c.

CHAPTER VII.

THE FORMATION AND DECOMPOSITION OF ACIDS.

I. Since all acids reſemble each other in their taſte, their manner of giving a red colour to vegetable ſubſtances, their tendency to combine with earths, alkalis, and metallic oxyds, and their property of attracting and being attracted powerfully, it was natural to preſume, as Newton obſerved, that they likewiſe reſembled each other in their intimate nature, and poſſeſſed ſome homogeneal principle: And chemical analyſis, by the help of the new means it has in its power to employ, has eſtabliſhed this as a truth beyond the poſſibility of doubt.

II. As every acid contains oxygen, and loſes its acidity exactly in proportion as it is deprived of this principle, we ought to conſider acids as burnt or oxygenated ſubſtances, which are akin to each other from the preſence of the acidifying principle.

III. There are two methods of acquiring a knowledge of the nature of acids: One by forming them, by compoſing them from their conſtituent parts, in uniting with oxygen ſuch ſubſtances as are capable of becoming acid by an union with it: The other by decompoſing them, by *unburning* them, in depriving them of their oxygen by the aid of ſubſtances with which this principle has great affinity.

IV. Conſidered in the laſt mentioned view, all known acids may be divided into three claſſes, namely, 1ſt, Thoſe which may be both compoſed and decompoſed, of which our knowledge is moſt complete: 2dly, Thoſe which we can only compoſe, being incapable of decompoſing them; and with theſe alſo we are well acquainted: 3dly, Thoſe which have never yet been either compoſed, or decompoſed; the nature of which remains altogether unknown.

V. Since, out of thirty known ſpecies of acids, as there are but three, ſtrictly ſpeaking, which are in the laſt predicament, or which we can neither compoſe nor decompoſe, ſo that we are neceſſarily ignorant of their nature, there is no reaſon why we ſhould not regard ſubſtances of this kind as accurately diſcriminated, and contemplate their general properties and compoſition.

VI. All acids being compounds of oxygen with different ſubſtances, the former principle is the cauſe of their reſemblance and common properties; the latter, being different in each, may ſerve to characterize each in particular. For this reaſon, thoſe matters which are variable in acids are termed their *radicals*, or *acidifiable* principles.

VII. Thus all acids are combinations of radicals, or acidifiable ſubſtances, different in each ſpecies, with oxygen, which is the ſame in all: Whence it follows, that their common properties, their characters as acids, depend on oxygen; their particular properties, their ſpecific characters, ariſe from their radicals.

VIII. The word *acid*, indicating the general and identical nature of theſe ſubſtances, forms their generical name, while the particular name of the radical contained in each may with propriety deſignate each particular acid. Thus ſulphur is the radical of the acid we name *ſulphuric*, phoſphorus that of the *phoſphoric*, carbon that of the *carbonic*, and ſo on.

IX. Though this nomenclature enjoys the advantage of expreſſing the nature of each acid, we are unable to employ it for all, becauſe the radicals of ſome are unknown, and thoſe of others are themſelves compounded of ſeveral principles, and would conſequently require too complicated appellations.

X. Acidifiable radicals may contain different quantities of oxygen, and under this point of view they poſſeſs two ſtates of acidity. The firſt is that, in which they contain the leaſt poſſible quantity of oxygen to render them acid. In this their acidity is commonly weak, and they adhere but feebly to the baſes with which they are capable of forming ſalts. The modern methodical nomenclature deſignates this ſtate of combination and acidity, by giving the names of theſe weak acids the termination *ous*. Thus we ſay the ſulphurous, nitrous, phoſphorous, or acetous acid. The ſecond ſtate of acids is that, in which they contain more oxygen, and in general are completely ſaturated with it. In this they have all the ſtrength and attraction they are capable of poſſeſſing as acids, and the modern nomenclature expreſſes it by the termination *ic*. Thus we ſay the ſulphuric, nitric, phoſphoric, or acetic acid.

XI. With regard to the proportion of oxygen united to acidifiable radicals, ſtill greater latitude may be given to the conſiderations preſented in the foregoing paragraph. Each radical may be contemplated in four ſtates: 1ſt, Containing very little oxygen, not ſufficient to impart to it the nature of an acid, and in this it is nothing more than an oxyd: Such is ſulphur coloured red or brown, by expoſure to the air, and a degree of heat inadequate to produce inflammation; when it is oxyd of ſulphur: 2dly Containing more oxygen than in the preceding caſe, and enough to become an acid, though weak; as in the ſulphurous acid: 3dly, Poſſeſſing ſtill more oxygen than in the ſecond inſtance, and having acquired powerful acid properties: Such is the ſulphuric acid: 4thly, Conjoined with a larger doſe of oxygen than is neceſſary to conſtitute a powerful acid, an acid in *ic;* when it is termed an oxygenated acid, or even ſuperoxygenated.

XII. From the conſiderations above enumerated, it follows, that we have two modes of forming at will acids with different proportions of oxygen. One is, to combine the radicals with ſuch determinate quantities of oxygen as are neceſſary to convert them into the ſtate required, as is done with ſulphur, phoſphorus, or arſenic: The other to extract from acids containing the greateſt poſſible quantity of oxygen, different proportions of this principle, by means of combuſtible ſubſtances which abſorb it with great avidity.

XIII. The latter method, founded on the affinity of oxygen for different combuſtible ſubſtances, is frequently employed with ſucceſs for the complete decompoſition of acids, by depriving them of all the oxygen they contain. It is in this way, that acids inflame combuſtible ſubſtances. To produce this effect it is ſufficient, that the acids employed do not contain oxygen in a ſtate of ſolidity, and that the inflammable matter brought into contact with it will abſorb it in a more ſolid ſtate than that in which it ſubſiſts in the acid. But theſe conditions being requiſite, inflammation by no means takes place in all decompoſitions of acids by combuſtible ſubſtances.

XIV. Hot charcoal is ſucceſsfully uſed to decompoſe all acids ſuſceptible of decompoſition; but it is not the only combuſtible ſubſtance, that will anſwer the purpoſe; for moſt metals, phoſphorus, ſulphur, and hydrogen in a dry and ſolid ſtate, as it exiſts in vegetable compounds, poſſeſs the ſame property.

XV. All the acids, the ſpecific nature of which is owing to their particular radicals, as has been already ſaid, may be divided into four claſſes, according to the nature of their baſes being known or unknown, ſimple or compound.

A. The firſt claſs includes acids with known and ſimple radicals, or ſuch as are formed by the union of indecompoſable combuſtible ſubſtances with oxygen. Its ſpecies are the following: Sulphuric acid, nitric acid, carbonic acid, phoſphoric acid, arſenic acid, tungſtenic acid, and molybdenic acid.

B. The ſecond claſs compriſes acids with radicals that are unknown, but ſtrongly ſuſpected of being ſimple. In it may be reckoned the muriatic acid, fluoric acid, and boracic acid.

C. In the third claſs I rank acids with binary compound radicals. Such are all the vegetable acids, the common radical of which is a compound of hydrogen and carbon. In this claſs the ſuccinic acid ſhould alſo be placed.

D. To the fourth claſs belong all acids of which the radicals are at leaſt triple compounds. In this are comprehended the animal acids, the radicals of which are combinations of carbon, hydrogen, and azot.

XVI. Not only is each of the claſſes in the preceding ſection diſtinguiſhable by general characters inherent in it, but each individual acid alſo poſſeſſes properties, by which it is characterized, and which prevent its being confounded with any other. And theſe properties may even be denoted by ſimple and eaſy expreſſions, by phraſes ſimilar to thoſe which naturaliſts have learnt from Linnæus to employ. A ſketch of this method will be exhibited in the following ſections.

XVII. All acids with ſimple and known radicals are capable of being decompoſed by combuſtible bodies, which they burn with more or leſs rapidity, and are thus reduced to their radicals. It is even by means of this decompoſition, that the nature of their radicals becomes known. We can alſo form them from their conſtituent principles, by uniting their radicals with oxygen.

Acids with unknown radicals, which are ſuſpected of being ſimple ſubſtances from ſtrong analogy, have no other claſſic character than thoſe of being inſuſceptible of decompoſition by means of combuſtible ſubſtances, and incapable of being formed by art.

Acids with binary radicals, or vegetable acids, are diſtinguiſhable by the following characters. 1. They are all decompoſable by a ſtrong fire and a ſufficient addition of oxygen. 2. In this decompoſition they afford water and carbonic acid, formed by the disjunction of their hydrogen and carbon, each of which unites ſeparately with a portion of the oxygen. 3. They are decompoſed ſpontaneouſly and ſlowly in a temperature above 53°, if diſſolved in water. 4. They cannot be decompoſed by any known combuſtible body, their radical being compounded of two ſubſtances which have the ſtrongeſt attraction for oxygen of any with which we are acquainted. 5. They are convertible into each other; which is owing to the difference between them conſiſting ſolely in the proportion of their three conſtituent principles.

Acids with ternary radicals, and thoſe which are ſtill more compound, or animal acids, though the leaſt known of all, poſſeſs ſome properties which may be deemed claſſic characters. Such are thoſe of affording ammoniac when decompoſed by fire, and furniſhing pruſſic acid on the proportion of their principles being changed.

XVIII. To theſe claſſic characters their ſpecific characters muſt be added, attempting a language analogous to that of the botaniſt and zoographer.

Acids of the firſt claſs, or with ſimple and known radicals.

A. Sulphuric acid, formed of ſulphur and oxygen by the combuſtion of ſulphur, inodorous, twice as heavy as water, very cauſtic, leſs volatile than water, affording ſulphurous acid gas and ſulphur on being decompoſed by red-hot charcoal, metals, &c., and forming ſulphats with earths, alkalis, and metallic oxyds.

B. Sulphurous acid, having a powerful ſmell, very volatile, gaſeous, deſtructive of blue vegetable colours and removing ſtains produced by theſe colours on white, gradually attracting oxygen from the air, and ſeveral acids or oxyds, and forming ſulphits with earthy and alkaline baſes.

C. Nitric acid, liquid, white, cauſtic, of a ſtrong and nauſeous ſmell, formed of azot and oxygen, inflaming ſulphur, charcoal, zinc, tin and oils, yielding to combuſtible bodies various portions of oxygen, and thus giving birth to nitrous acid, nitrous gas, or nitrous oxyd, deſtroying colours, burning and turning yellow vegetable and animal ſubſtances, converting them into acids, decompoſing ammoniac, produced by putrefying animal matter, forming nitrats with earths and alkalis, remaining ſlightly united with metallic oxyds, and tending to acidify them.

D. Nitrous acid, the ſame as nitric acid, except in having a ſmaller portion of oxygen, red or orange coloured in the ſtate of gas, very volatile, depriving vegetables of colour, becoming blue and green on the addition of water, turning yellow nitric acid, to which it is united in different proportions, yielding nitrous gas on the contact of combuſtible ſubſtances, and forming nitrits with earths and alkalis.

E. Carbonic acid, formed of twenty-eight parts of carbon with ſeventy-two of oxygen, a gas heavier than air and diſplacing it, filling ſubterraneous cavities, diſſengaging itſelf from liquors in a ſtate of vinous fermentation, extinguiſhing lighted candles, killing animals, reddening only light vegetable blues, precipitating chalk from lime-water, re-diſſolving the chalk in the water, mineralizing acidulous waters, baryt, lime, copper, iron, and lead, in quarries and mines, forming carbonats with earths, alkalis, and metallic oxyds, decompoſable by phoſphorus alone, and when it is united to alkaline baſes, particularly ſoda in the ſtate of carbonat.

F. Phoſphoric acid, compoſed of phoſphorus and oxygen united by rapid and complete combuſtion, liquid, denſe, or ſolid, vitrifiable by means of fire, diſſolving ſilex in the act of vitrification, decompoſable by carbon which reſtores it to the ſtate of phoſphorus, and forming phoſphats with earths, alkalis, and metallic oxyds.

G. Phoſphorous acid, differing from the phoſphoric only in containing leſs oxygen, volatile, odorous, eliciting oxygen from various bodies, and forming phoſphits with earthy, alkaline, and metallic baſes.

H. Arſenic acid, formed of the metal called arſenic and oxygen *, fixed, fuſible into a glaſs, decompoſable by means of a

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* Combuſtion reduces arſenic to an oxyd only; nitric acid, or oxygenated muriatic acid, adds to this oxyd the quantity of oxygen neceſſary to convert it into arſenic acid.

large quantity of light and caloric, as well as by ſeveral combuſtible ſubſtances, and forming arſeniats with earths, alkalis, and metallic oxyds. Oxyd of arſenic, being alſo capable of uniting with theſe baſes, may be conſidered as a ſort of arcenious acid.

I. Tungſtenic acid, compoſed of the metal called tungſten and oxygen, a white or yellowiſh powder, fixed, infuſible, difficultly ſoluble, reducible to tungſten by means of *hydrogen*, carbon, &c. forming the native tungſtat of lime called *lapis ponderoſus*, and the native tungſtat of iron, or wolfram of mineralogiſts.

K. Molybdenic acid, compoſed of the metal named molybdena and oxygen, of a rough taſte, metallic like the two preceding ſpecies, in a white powder, becoming blue on the contact of ſuch ſubſtances as reduce it, and in conſequence of the loſs of oxygen returning to the ſtate of molybdena.

Acids of the ſecond claſs, or with unknown radicals.

XIX. There are three acids, the radicals of which are unknown, though ſuſpected to be ſimple: The muriatic, fluoric, and boracic.

A. Muriatic acid, gaſeous or fluid, of a pungent ſmell, unalterable by any known combuſtible ſubſtance, on the contrary attracting oxygen from ſeveral burnt bodies, particularly from metallic oxyds, and thus becoming *oxygenated muriatic acid.* The oxygenated muriatic acid is remarkable for its greeniſh yellow colour, its action on the organs of animals which it thickens and contracts, its properties of diveſting vegetable ſubſtances of colour, burning and inflaming moſt combuſtible ſubſtances, and forming with potaſh a ſalt, which rapidly ſets fire to heated inflammable ſubſtances, and affords the pureſt vital air known.

B. Fluoric acid, gaſeous, forming a very thick white vapour in the air, corroding glaſs, diſſolving ſilicious earth, and forming with this earth a permanent gas, from which water ſeparates a part of the ſilex.

C. Boracic acid, dry, cryſtalized in hexædral laminæ, fuſible into a glaſs, poſſeſſing little taſte, difficultly ſoluble, melting with ſilex, having very feeble affinities, and reſigning earthy or alkaline baſes to almoſt all other acids.

Acids of the third claſs, or with binary radicals.

XX. Acids with binary mixed or compound radicals belong particularly to the vegetable kingdom, and are formed by the union of carbonated hydrogen or hydrogenated carbon with oxygen in different proportions, which accounts, as has already been ſaid, for their reciprocal converſion into each other. Theſe acids being pretty numerous, and capable of becoming ſtill more ſo by daily diſcoveries, I have divided them into five genera, in which I have regard to their nature and formation. The firſt genus includes the pure acids formed in vegetables, reckoning amongſt theſe the ſuccinic acid, which is manifeſtly of vegetable origin. In this there are five ſpecies: The ſuccinic, citric, gallic, malic, and benzoic acids. The ſecond compriſes vegetable acids perfectly formed, but partly ſaturated with potaſh. Of theſe, which are termed aſcidules, there are two ſpecies, the tartarous and oxalic. In the third genus I claſs the particular acids formed by the agency of the nitric acid, and the precipitation of its oxygen upon vegetable ſubſtances. We have yet but one diſtinct ſpecies in this genus, the camphoric acid; though the oxalic and malic acids are frequently formed by treating vegetable ſubſtances with the nitric acid. In the fourth genus I place the acids formed in vegetables treated with fire. Such are the pyromucous, pyroligenous, and pyrotartarous acids. The fifth genus comprehends vegetable acids produced by fermentation, of which we are acquainted with only one, the acetous. The following are the ſpecific characters of the twelve acids here enumerated.

A. Succinic acid, diſengaged and ſublimed from heated amber, of a ſtrong bituminous ſmell, oleaginous and inflammable, volatile, cryſtallizable in the ſhape of needles, forming permanent cryſtallizable ſalts, particularly with metallic oxyds, and adhering more forcibly to the three alkaline earths than to alkalis.

B. Citric acid, cryſtalizable in rhomboidal laminæ, not convertible into oxalic acid by means of the nitric, having more affinity to earths than to alkalis, and ſpontaneouſly decompoſable in water, and by the action of fire.

C. Gallic acid, abounding in galls, cryſtallized in little gray or yellowiſh needles, ſtyptic, precipitating iron black from its ſolutions, reducing metallic oxyds united to other acids, and convertible into oxalic acid by means of the nitric.

D. Malic acid, abounding in apples, not cryſtallizable, convertible into oxalic acid by means of the nitric, and forming at the ſame time with the malic acid, and even before it, in vegetables treated by the nitric acid.

E. Benzoic acid, obtained from benzoin, ſtorax, balſam of Peru, vanilla, and cinnamon, by means of heat, cryſtallizable into compreſſed priſms, of an aromatic ſmell when warmed, fuſible by a gentle fire, volatile, inflammable, little ſoluble in water, ſoluble in the nitric acid, but not decompoſable by it.

F. Tartarous aſcidule, formed of tartarous acid partly ſaturated with potaſh, exiſting in wine, cryſtallizable, decompoſable by fire, affording a conſiderable quantity of carbonic acid and oil, and leaving behind much carbonat of potaſh, yielding alſo on diſtillation pyrotartarous acid, little ſoluble, decompoſable in water, forming triple ſalts with alkalis and metallic oxyds, and becoming very ſoluble by the addition of borax or boracic acid. The tartarous acid, obtained from the aſcidule, is cryſtallizable in needles interwoven amongſt each other, unalterable in the air, very ſoluble, forming anew the acidule by the addition of a little potaſh, decompoſing the ſulphats, nitrats, and muriats of potaſh and ſoda, till they reciprocally form acidules, and convertible into oxalic acid by means of the nitric.

G. Oxalic acidule, formed of oxalic acid partly ſaturated with potaſh, extracted from the juice of ſorrel, cryſtallized in parallelopipeds, little decompoſable by fire, affording no oil, little ſoluble, and forming triple ſalts with earths and alkalis. The oxalic acid extracted from it is very ſoluble, and very cryſtallizable, attracts lime from all other acids, perfectly reſembles that which is formed from all vegetable ſubſtances by the contact of nitric acid, and is the leaſt decompoſable and moſt oxygenated of the vegetable acids.

H. Camphoric acid, produced by diſtilling camphor with nitric acid, cryſtallizable in parallelopipeds, forming perfectly cryſtallizable ſalts with earths and alkalis, and not attracting lime from all the other acids as oxalic acid does. This acid is very little known.

I. Pyrotartarous acid, a modification of the tartarous acid produced by fire, of an empyreumatic ſmell, and burnt colour, very rarefiable and ſwelling up greatly with caloric, not cryſtallizable, and forming with earthy and alkaline baſes, ſalts different from thoſe afforded by the tartarous acid. With this acid we are but little acquainted.

K. Pyromucous acid, formed by the diſtillation of gums, ſugar, or feculæ, poſſeſſing very powerfully the agreeable ſmell of a lozenge, volatile, colouring vegetable and animal ſubſtances, red and decompoſable by a ſtrong fire. This alſo is little known.

L. Pyroligneous acid, extracted from wood by diſtillation, of a pungent fetid ſmell, not cryſtallizable, decompoſable by a ſtrong fire, volatile, forming peculiar ſalts with earths, alkalis, and metallic oxyds, and having particular attractions for theſe baſes, but in other reſpects we are as little acquainted with it as with the two preceding acids.

M. Acetous acid, formed by the fermentation of wine, on which account it is called vinegar, of an agreeable ſmell and taſte, volatile and liquid, decompoſable by a ſtrong fire, capable of being ſurcharged with oxygen when diſtilled with metallic oxyds, and thus becoming acetic acid, or radical vinegar, which is more acrid and odorous than the acetous acid, inflammable, and mixed with alcohol.

Acids of the fourth claſs, or with ternary radicals.

XXI. Acids with ternary compound radicals, which were ſpoken of above as formed in general of carbon, hydrogen, and azot, united with oxygen, appertain more eſpecially to animal ſubſtances. With theſe we are ſtill leſs acquainted than with the preceding acids: But recalling here to the reader's mind, that they all furniſh ammoniac on being decompoſed by the action of fire, and pruſſic acid on a change in the proportion of their principles, I ſhall remark, that the pruſſic acid ſeems to be to theſe acids in general what the oxalic is to vegetable acids, and add, that on converting animal ſubſtances into oxalic acid by the agency of nitric acid, pruſſic acid is conſtantly formed during the operation, and evolved in the ſtate of vapour.

There are ſeven animal acids known, all of which appear to belong to this claſs of compounds, namely, the lactic, ſaccholactic, ſebacic, lithic, formic, bombic, and pruſſic acids. In each let us ſeek for a few characteriſtic properties.

A. Lactic acid, formed, with a little acetous acid, in milk ſpontaneouſly ſoured, not cryſtallizable, ſoluble in alcohol, affording on diſtillation an acid analogous to the pyrotartarous, forming deliqueſcent ſalts with earthy and alkaline baſes, and decompoſing alkaline acetits.

B. Saccholactic acid, precipitating as a white powder from oxalic acid formed by ſugar of milk and nitric acid, little ſapid, ſcarcely at all ſoluble, decompoſable by fire, when a ſalt reſembling benzoin in ſmell ſublimes from it, and forming cryſtallizable ſalts with alkalis. This is very little known.

C. Sebacic acid, obtained from fat by the action of fire, ſeparated from it alſo by alkalis and lime with the affiſtance of a ſtrong heat, liquid, white, ſmoking, very acrid in taſte and ſmell, forming cryſtallizable and fixed ſalts with earth and the alkalis, decompoſing muriat of mercury, and decompoſable by a ſtrong heat.

D. Lithic acid, exiſting in human urine, forming the ſtone in the bladder, dry, cryſtallized in flat needles, almoſt inſipid and inſoluble, in part volatile, decompoſable by a ſtrong heat, affording ammoniacal carbonat and pruſſic acid by the agency of fire, forming a beautiful red ſolution with nitric acid, ſoluble in cauſtic alkalis, and precipitating of a gridelin or reddiſh colour from the urine of perſons labouring under fever.

E. Formic acid, obtained from ants by diſtillation or expreſſion with water, reddening blue flowers while in the living inſect, flying off in a very highly odorous vapour, in ſmell analogous to muſk, killing animals in this form of gas, capable of being employed for the ſame domeſtic purpoſes as vinegar, decompoſable by a ſtrong fire, taking oxygen from oxygenated muriatic acid, frequently ſtronger than ſulphuric acid, and forming cryſtallizable and not deliqueſcent ſalts with earths and alkalis.

F. Bombic acid, contained in a reſervoir near the anus of the chryſalis of the ſilk-worm, extracted from this reſervoir either by expreſſion or by means of alcohol, mingled with a brown oil and a gum while in the worm, liquid, of an amber yellow colour, decompoſable ſpontaneouſly, and affording pruſſic acid by means of diſtillation and nitric acid. In its combinations it is unknown.

G. Pruſſic acid, ſaturating iron and colouring it in pruſſian blue, obtained at preſent by the diſtillation of blood, or the action of nitric acid on albumen, gluten, animal fibre, &c., and diſengaged in proportion as oxalic acid is formed, remarkable for a noxious fetid ſmell, analogous to that of bitter almonds, very decompoſable by a ſtrong fire, and then affording ammoniac, ſuſceptible of the form of gas, taking metallic oxyds from a great number of other acids, capable of being artificially formed by the union of hydrogen, carbon, azot, and oxygen, little acid in its taſte, and containing, as far as appears, very little oxygen.

XXII. It follows, from what has been advanced in the preceding ſections, that if acids be divided into two claſſes, diſtinguiſhed by having ſimple or compound radicals, they will be found to differ principally in this circumſtance, that thoſe with ſimple radicals are not convertible into each other, becauſe the properties of one ſimple radical, ſulphur for example, vary much from thoſe of another, ſuch as phoſphorus, whence it would be neceſſary to begin with converting theſe radicals into each other, which is far beyond the power of art: The acids of the other claſs, on the contrary, being formed in general of a baſe compoſed of hydrogen, carbon, and azot, united with oxygen, appear to differ from each other only in the proportions of the two or three principles which enter into the compoſition of their radicals, and of the oxygen united with theſe, have a tendency to undergo inceſſant changes in their compoſition, eſpecially from variation of temperature, humidity, &c., and ſpontaneouſly paſs into different ſtates. Thus, from the mere efforts of vegetation, plants contain different acids at different periods of their growth: And thus ſolutions of vegetable acids in water change, alter their nature, and ultimately yield a certain quantity of carbonic acid and water, as they arrive at the laſt ſtage of decompoſition.

XXIII. If we attend to theſe facts, it is eaſy to perceive that there ſtill remain to be diſcovered, not only the nature of ſeveral acids, with the compoſition of which we are unacquainted, but alſo perhaps a conſiderable number of new acids, in plants and animals. For among the productions of theſe organized beings, the principles of which we have only begun to inveſtigate, we are far from having exhauſted all the poſſible combinations of carbon, hydrogen, azot, and oxygen, as the moſt ſuperficial calculation will demonſtrate. To this order of inveſtigation and diſcovery, we muſt refer the examination of the acids indicated in cork, gray-peaſe, and ſeveral other vegetable matters, as well as thoſe of the gaſtric juice, the coagulum of the blood, *cruoric acid*, &c. It will be perceived too, from the ſucceeding chapter, that moſt burnt metals ſeem to enter into the claſs of acids, and comport themſelves as theſe ſalts, in a great number of combinations: So that acids appear to be the moſt numerous of all bodies, and perform the principal parts in the chemical alterations, which both ſimple and compound ſubſtances are deſtined inceſſantly to undergo.

Application of the Propoſitions reſpecting Acids.

The artificial formation of ſulphuric acid, by the combuſtion of ſulphur in the great.
The diſcharging of colour from white linens and ſtuffs, by means of the ſulphurous acid.
The new art of bleaching, by means of the oxygenated muriatic acid.
The theory of the *aqua regia* of the ancient chemiſts.
The art of engraving on glaſs, by the fluoric acid.
One part of the theory of the formation of artificial nitre-pits.
The exiſtence and formation of the known native acids.
The influence of acids in mineralization.
The extraction and purification of vegetable acids and acidules.
The ſpontaneous formation and deſtruction of vegetable acids.
Their reciprocal converſion into each other, by vegetation, fermentation, &c.

CHAPTER VIII.

OF THE UNION OF ACIDS WITH EARTHS AND ALKALIS.

I. ALL acids unite with alkalis and the alkaline earths, without being decompoſed. The combinations thus formed, have been called neutral, middle, compound, or ſecondary ſalts. To the firſt two of theſe names they have no claim, unleſs when they are neither acid nor alkaline: The other two are more accurate, and of greater utility. All theſe ſalts are readily made by art; and nature exhibits a conſiderable number of them, particularly of thoſe the radicals of which are ſimple. Mineralogy is continually making new acquiſitions in this branch of knowledge, by the analyſis of minerals, which alone is capable of unfolding to us their intimate nature.

II. Every compound ſalt ought to have a double name, one branch of which ſhould indicate its acid, the other its earthy or alkaline baſe. The former has two different terminations announcing the ſtate of the acid. Words ending in *at* are employed when the ſalt contains an acid ſaturated with oxygen, which is denoted by the termination *ic*: Thus *nitrats* are formed by the *nitric* acid: And words ending in *it*, imply feeble acids, not ſaturated with oxygen; for which, as has been already obſerved, we uſe the termination *ous:* Thus the compounds of the *nitrous* acid are *nitrits.*

III. As there are thirty-four kinds of acids known, and ſeven earthy or alkaline baſes, which may be united to form compound ſalts, the number of theſe ſalts might be eſtimated at two hundred and thirty-eight; but ſuch a calculation would be far from exact; for, 1ſt, There are only few acids capable of combining with ſilex; 2dly, There are others which cannot unite with certain earthy baſes, on account of their weakneſs, or with ammoniac without decompoſing it; 3dly, There are ſeveral acids which may be united to the ſame baſes in three ways, or remain at three different points of ſaturation with theſe baſes; namely, with exceſs of acid, with exceſs of baſe, and exactly neutralized. Thus we are far from being able to determine with accuracy the number of earthy and alkaline compound ſalts; becauſe we are far from having ſufficiently examined all theſe combinations, to attain a perfect knowledge of them, and aſſure ourſelves whether they be not ſuſceptible of ſeveral degrees of ſaturation, &c.

IV. All the acids poſſeſſing different elective attractions or affinities for each alkaline or earthy baſe, it is neceſſary to be fully acquainted with the whole of theſe reſpective affinities, before we can have a complete hiſtory of compound ſalts; and as a very few only of theſe affinities have yet been determined with accuracy, we are far from poſſeſſing the general maſs of facts that relate to this order of bodies. Indeed, one-tenth of theſe combinations has not yet been duly inveſtigated.

V. To begin the hiſtory of compound ſalts methodically, we muſt divide them into genera and ſpecies, and fix their generic and ſpecific characters. As this branch of the ſubject has not yet occupied the attention of chemiſts, a ſlight ſketch of it is all that can be given; though, in the preſent ſtate of ſcience, it is eſſential to employ the method of botaniſts, in the enunciation of chemical properties.

There are two methods of dividing compound ſalts, to which recourſe might be had; the one founded on their acids, the other on their baſes: At preſent, however, it is from the acids only we can eſtabliſh genera comprehending the whole of theſe ſalts, for they alone are capable of furniſhing generic characters; the influence of the baſes on the properties of theſe compounds, not being ſufficiently known, to enable us to conſider theſe earthy and alkaline ſubſtances, as the heads of the generical diviſions.

VI. Thus we may reckon thirty-five genera of compound ſalts, according to the number of the acids; and the generical names being taken from their acids, we have for theſe thirty-five genera, the following denominations:—

Genus I.	SULPHATS.
Genus II.	SULPHITS.
Genus III.	NITRATS.
Genus IV.	NITRITS.
Genus V.	CARBONATS.
Genus VI.	PHOSPHATS.
Genus VII.	PHOSPHITS.
Genus VIII.	ARSENIATS.
Genus IX.	ARSENITS.
Genus X.	TUNGSTATS.
Genus XI.	MOLYBDATS.
Genus XII.	MURIATS.
Genus XIII.	OXYGENATED MURIATS.
Genus XIV.	FLUATS.
Genus XV.	BORATS.
Genus XVI.	SUCCINATS.
Genus XVII.	CITRATS.
Genus XVIII.	GALLATS.
Genus XIX.	MALATS.
Genus XX.	BENZOATS.
Genus XXI.	TARTRITS.
Genus XXII.	OXALATS.
Genus XXIII.	CAMPHORATS.
Genus XXIV.	PYROMUCITS.
Genus XXV.	PYROLIGNITS.
Genus XXVI.	PYROTARTRITS.
Genus XXVII.	ACETATS.
Genus XXVIII.	ACETITS.
Genus XXIX.	LACTATS.

Genus XXX. . . Saccholats.
Genus XXXI. . . Sebats.
Genus XXXII. . . Lithiats.
Genus XXXIII. . . Formiats.
Genus XXXIV. . . Bombiats.
Genus XXXV. . . Pruſsiats.

VII. Each of the thirty-five genera of compound ſalts above enumerated ſhould be conſidered with reſpect to its diſcriminative characters, or thoſe qualities which are ſufficient to diſtinguiſh it, and give an accurate idea of its difference from all others. For this purpoſe, out of the properties diſplayed by it, one, if poſſible, or at moſt two or three, ſhould be ſelected, of prominent features, and conſtituting an eſſential character of each genus. I ſhall now attempt a ſketch of this ſort.

Genus I. Sulphats: Decompoſable by charcoal, &c. into ſulphures.

Genus II. Sulphits: Yielding the ſmell of burning ſulphur on the contact of almoſt all acids, with effervеſcence.

Genus III. Nitrats: Accending combuſtible bodies at different temperatures, and almoſt all of them reducible to their baſes by the action of fire.

Genus IV. Nitrits: Decompoſable by weak acids, which ſeparate from it red nitrous vapour.

Genus V. Carbonats: Leaving the characters of their baſes more or leſs prominent; and producing with all acids a briſk and ſenſible effervеſcence, till their carbonic acid is completely evolved.

Genus VI. Phosphats: Decompoſable mediately or immediately by charcoal, which ſeparates from them the phoſphorus.

Genus VII. Phosphits: All decompoſable immediately by charcoal, which ſeparates from them the phoſphorus; and emitting vapours on the contact of ſulphuric acid, &c.

Genus VIII. Arseniats: Affording, on the contact of red hot charcoal, the ſmell and white vapour of arſenic; and not decompoſable by acids alone, unaſſiſted by a double affinity.

Genus IX. Arsenits: The arſenious acid is ſeparated and precipitated from their ſolutions by the contact of all the acids, even of the arſenic acid.

Genus X. Tungstats: Turning yellow on the addition of nitric or muriatic acid.

Genus. XI. MOLYBDATS: Not yet diſtinguiſhable till the molybdenic acid is ſeparated from them by other acids, and in conſequence of the characters exhibited by the molybdenic acid.

Genus XII. MURIATS: Affording muriatic acid by means of concentrated ſulphuric acid, and oxygenated muriatic acid when acted upon by the nitric.

Genus XIII. OXYGENATED MURIATS: Accending all combuſtible bodies at a lower temperature than they are kindled by nitrats, with a more vivid flame, and remaining in the ſtate of muriats after the combuſtion is ended.

Genus XIV. FLUATS: Yielding a vapour that corrodes glaſs, on the contact of concentrated ſulphuric acid.

Genus XV. BORATS: Fuſible, with or without ſeparation of their baſes; and affording, when another acid is united with their ſolution, boracic acid in foliated cryſtals.

Genus XVI. SUCCINATS: Theſe are not to be known or characterized but by decompoſing them, and obſerving their acid: Moſt of them retain the ſmell of burnt amber.

Genus XVII. CITRATS: Not ſufficiently known for us to find in them generic characters: To diſtinguiſh them, the citric acid muſt be ſeparated by the moſt powerful mineral acids.

Genus XVIII. GALLATS: All ſtrongly characterized by their property of precipitating iron black from its ſolutions, and partly reducing the oxyds of ſilver, gold, and mercury, in ſeparating them from the menſtrua in which they are diſſolved.

Genus XIX. MALATS: Almoſt all deliqueſcent: Not to be known but by obtaining their acid ſeparately by the aid of mineral acids.

Genus XX. BENZOATS: Aſcertainable on diſcerning the ſmell of the benzoic acid, ſeparated by acids of greater power.

Genus XXI. TARTRITS: Sufficiently ſtriking characteriſtics for diſtinguiſhing theſe, are to be found in their tendency to compoſe triple ſalts, and acidules leſs ſoluble than either the pure acid, or the neutral ſalts which the tartarous acid forms with the ſame baſes.

Genus XXII. OXALATS: May be characterized by their tendency to form acidules of difficult ſolution, and their property of decompoſing all calcareous ſalts.

Genus XXIII. CAMPHORATS: Too little known to have generic characters aſſigned them: They are to be diſtinguiſhed by the preſence of the camphoric acid, and the recognition of its properties, when ſeparated.

Genus XXIV. Pyromucits: Similarly circumſtanced with camphorats.

Genus XXV. Pyrolignits: The ſame may be ſaid of theſe.

Genus XXVI. Pyrotartrits: Theſe rank with the three preceding genera.

Genus XXVII. Acetats: Yet too little diſtinguiſhed from acetits: Evolving, when decompoſed by mineral acid, a very ſtrong and pungent white vapour.

Genus XXVIII. Acetits: All recognizable by their acid diſengaged by means of ſharper acids.

Genus XXIX. Lactats: Very little known: Their acid, ſeparated by others, can alone characterize them.

Genus XXX. Saccholats: As the lactats: Unknown.

Genus XXXI. Sebats: Emitting the white vapour and acrid ſmell of ſebacic acid on the contact of the ſtrongeſt mineral acids.

Genus XXXII. Lithiats: The weakeſt of all ſalts in their attractions, being decompoſable even by the carbonic acid.

Genus XXXIII. Formiats: Very little known, and recognizable only by means of their acid.

Genus XXXIV. Bombiats: Similarly circumſtanced with the formiats.

Genus XXXV. Prussiats: Completely characterized by their property of forming pruſſian blue with ſolutions of iron.

VIII. To determine the ſpecific characters of nearly two hundred and forty-five ſpecies contained in theſe thirty-five genera, they would require to be profoundly ſtudied, and in this reſpect ſcience is yet little advanced. While our knowledge is thus defective, it is of importance to indicate at leaſt the path we ought to purſue, to complete the hiſtory of theſe compounds, and to aſcertain with preciſion the method of inveſtigating their properties.

Each compound earthy or alkaline ſalt preſents to our obſervation,

1ſt, Figure, and the varieties of that figure. This ought to be deſcribed geometrically: The inclination and degrees of its angles, the primitive formation of the cryſtals, the interior form, their diſſection, and the laws of decreaſe which determine their varieties, ſhould be detailed.

2dly, Its exiſtence by art or nature, with a compariſon of the native and artificial ſalt.

3dly, Taſte.

4thly, The action of fire; whether it be null, fuſing, vitrifying, ſubliming, or decompoſing, &c.

5thly, That of light.

6thly, The influence of the air; whether it be null, or impart water to the cryſtals, or elicit water from them.

7thly, The union with water, the quantity neceſſary to diſſolution at different temperatures, the caloric abſorbed or evolved, the cryſtallization produced by refrigeration or evaporation.

8thly, The attraction of earths which modify the ſalt, decompoſe it, produce no change in it, or unite with it to form a triple ſalt.

9thly, The effect of alkalis on it; whether null, decompoſing, or ſometimes combining with it, ſo that a triple ſalt is formed.

10thly, The comparative action of acids different from that which it contains, decompoſing the ſalt, changing its nature, or producing in it no alteration.

11thly, The operation of other neutral ſalts on it; which may produce a complete union, forming a triple ſalt; a double decompoſition, by an interchange of acids and baſes; a precipitation, in conſequence of their attraction for water; or no alteration whatever.

12thly, The diſſolubility or indiſſolubility of the ſalt in alcohol.

13thly, Its alterability or unalterability by means of charcoal, which may diſcompoſe its acid, or leave it untouched.

14thly, The influence of vegetation and fermentation on the ſalt.

15thly, and finally, Its action on the animal economy.

IX. If all theſe queſtions were anſwered with preciſion, in the preſent ſtate of chemiſtry, the hiſtory of earthy and alkaline compound ſalts would not only be complete, but would throw conſiderable light on various phenomena of nature and art, which ſtill remain plunged in great obſcurity.

X. Some ſaline combinations of an acid with two baſes, particularly magneſia and ammoniac, are already known: Theſe compounds bear the name of *triſules*, or triple ſalts; but a far greater number exiſts, of which we are not ſufficiently aware, and which demand all the attention that can be paid them by chemiſts. The earth conceals, both at its ſurface and in its ſuperficial cavities, ſaline compounds differing from thoſe which art produces by the ſimultaneous exiſtence of two baſes, or even of two acids: Borat of lime and borat of magneſia have already been found cryſtallized together in cubic quartz, phoſphat of lime, and fluat of lime, in the earth of Marmaroch and the Eſtremadura ſtone, &c.

Applications of the Propoſitions in this Chapter.

The knowledge of native ſalts.
The cryſtallization and purification of uſeful ſalts.
The phenomena of ſolutions.
The precipitation and preparation of alumin, magneſia, &c.
The attraction of lime, potaſh, ſoda, and ammoniac for acids.
The formation of neutral ſalts by nature.
All the details of halotechny.
The preparation of the nitric, muriatic, boracic, and ſeveral other acids.

CHAPTER IX.

THE OXYDATION AND DISSOLUTION OF METALS.

I. METALS have already come under conſideration in the ſixth chapter, as indecompoſed or ſingle combuſtible bodies, and been characterized by their moſt ſtriking properties. But theſe general obſervations are not ſufficient: The important parts performed by theſe ſubſtances, in the phenomena of nature and the proceſſes of the arts, require, that they ſhould be ſeparately examined, and with ſufficient minuteneſs to enable us to appreciate the whole of their influence.

II. Though metals are capable of uniting in their metallic ſtate with each other, with ſulphur, with phoſphorus, with carbon, and with combuſtible ſubſtances in general, it is much more common to ſee them combined with oxygen previous to their union with other bodies; or, in other words, for them to enter into the greater number of compounds of which they conſtitute a part, it is neceſſary, that they firſt unite with oxygen, or be converted into the ſtate of burnt bodies. Accordingly, all the ſingular phenomena diſplayed by metals in their combinations, and the changes of form they undergo, are owing to their attraction for oxygen, and the different proportions in which they contain this principle.

III. Though there are various circumſtances under which metals may be united with oxygen, they may be reduced in general to three. The firſt is the contact of air, aſſiſted by caloric; the ſecond is owing to the decompoſition of water; the third, to that of acids. In this triple view the oxydation and diſſolution of metals are here to be conſidered.

IV. All metals heated in the air, and raiſed to a temperature more or leſs high, are ſuſceptible of burning with a vivid flame, great heat, and a true deflagration, either previous or ſubſequent to their entering into fuſion: thus they abſorb oxygen in a ſtate of greater or leſs ſolidity: Thoſe which oxydate ſlowly, and without perceptible inflammation, equally diſengage light and caloric from the vital air, but in ſo ſmall a quantity at a time, that they are not rendered ſenſible to our organs.

V. Elevation of temperature favours the abſorption of the oxygen of the atmoſphere by metals, and renders the combination of this principle with theſe combuſtible bodies more ſolid.

VI. While there are ſome metals which never burn in the air, except at a very high temperature, as gold, ſilver, and platina, there are others that burn at all temperatures, even the loweſt, and with great promptitude; as mangaueſe, which oxydates, and falls into powder, in a few hours, on the contact of air ſeveral degrees below the freezing point. Some, as iron, copper, lead, burn ſlowly, and in the courſe of ſome months, in the air, even though cold.

VII. All metals increaſe their weight during this operation, which does not take place without the contact of air, and conſequently abſorb a principle, the oxygen of the atmoſphere, without loſing any one. Neither the name of calcination, which was given to this phenomenon, nor that of metallic calces, can be retained; but inſtead of theſe have been ſubſtituted the terms of combuſtion and oxydation for the operation, and of metallic oxyds to denote the metals thus burnt.

VIII. The colours which metals diſplay in burning, or with which their flame is tinged, appear to be owing to the diſſolution of the metallic molecules in the light that is evolved. Thus copper yields a green flame, &c.

IX. Not only do all metals compared with each other abſorb different quantities of oxygen to ſaturate them in their combuſtion by the contact of air, but each metal conſidered ſeparately abſorbs different proportions, and ſtops at various points of oxydation, according to the degree of temperature to which it is raiſed. Thus tin, lead, copper, iron, change colour and aſſume the tints of the rainbow, at the firſt degree of fire to which they are expoſed in contact with the air: Lead firſt becomes a gray oxyd, next yellow, and laſtly red: Mercury paſſes from black to white, from white to yellow, and from yellow to red: Iron, at firſt a black oxyd, becomes next green, then brown, and ultimately white: Copper is at firſt a brown oxyd, from which it changes to blue, and its laſt degree of oxydation imparts to it a green colour.

X. All metals differ in their attraction for oxygen. From ſome, as gold, ſilver, &c., oxygen is elicited by means of light almoſt alone, or aſſiſted with a very ſmall portion of caloric; others, as mercury, require for its ſeparation a great degree of fire, and much light; while the greater number do not part with this principle, merely by the intervention of light and caloric. To decompoſe oxyds of the laſt deſcription, they muſt be heated with charcoal, which attracts from them their oxygen.

XI. It is owing to this diverſity of attractive power for oxygen, that ſome metals are deprived of it by others, as ſilver and gold are by almoſt all the reſt, mercury by copper, copper by iron, &c. We are not yet perfectly acquainted with all theſe degrees of attraction, but the preſent ſtate of our knowledge indicates the following order of the metals, beginning with that of which the attraction for oxygen is moſt powerful: Manganeſe, zinc, iron, tin, copper, mercury, ſilver, gold.

XII. Various metals decompoſe water, and this the more ſenſibly and rapidly the higher their temperature is raiſed, becauſe then the abundant quantity of caloric employed more forcibly attracts and diſſolves the hydrogen. Thus iron decompoſes water with great rapidity when it is of a white heat, though it requires a conſiderable time to effect its decompoſition at the higheſt temperature our atmoſphere ever attains.

XIII. Iron, zinc, tin, and antimony, appear to be capable of decompoſing water: It is probable, too, that manganeſe, and even ſome other metallic ſubſtances, are equally capable of effecting this purpoſe. This decompoſition is attributable to a ſtronger attraction for oxygen, than hydrogen poſſeſſes: Whence it follows, that hydrogen completely decompoſes the oxyds of thoſe which do not decompoſe water. But it is requiſite here to diſtinguiſh the different degrees of oxydation: For the oxyd of iron highly oxydated, or oxydated brown, is partly decompoſed by hydrogen, and reverts to the ſtate of black oxyd, becauſe iron is capable of iliciting oxygen from water only to that degree which oxydates it black, and beyond this degree of oxydation decompoſes it no longer.

XIV. All metals capable of decompoſing water effect this operation with more eaſe and rapidity, when aſſiſted by the contact of a ſubſtance which has a great tendency to unite with their oxyds. Frequently even metals, like other combuſtible bodies, which alone would not decompoſe water, are rendered capable of it by the preſence of ſome other ſubſtance, which acts by a prediſponent affinity. Thus almoſt all metals are enabled to effect the decompoſition of water by means of acids.

XV. Metallic oxyds have this peculiarity in their combinations, that they ſeem, with regard to acids, to perform the functions of alkalis, or earthy and alkaline baſes; though, on the other hand, they are capable of uniting with earths and alkalis, as if they were a ſort of acids. Of the latter, indeed, there are fewer than the former; and it is obſervable, that they which ſaturate alkalis in the manner of acids, are in general thoſe to which oxygen moſt powerfully adheres, as antimony, lead, iron, and manganeſe. It has already been ſaid, in Chapter VI. that there are three metals which are truly acidifiable.

XVI. Metals cannot be diſſolved by acids without being previouſly oxydated: For this reaſon, ſuch metallic oxyds as are ſoluble in acids, diſſolve in them ſlowly, and without effervefcence; while metals themſelves cannot be diſſolved in the ſame menſtruum, without motion and effervefcence being produced.

XVII The effervefcence occaſioned by the diſſolution of metals ariſes from this, that, in abſorbing oxygen, they take it from a principle which aſſumes the form of gas, or elaſtic fluid. This principle proceeds either from the water, or from the acid, employed in the proceſs, according as the one or the other is decompoſed; and ſometimes it originates from both, when both are decompoſed at the ſame time by the metal.

XVIII. Sulphuric acid thus decompoſed by metals, when in a concentrated ſtate, gives out ſulphurous gas; and nitric acid, nitrous gas.

XIX. Sulphuric acid diluted with water, greatly facilitating the decompoſition of the aqueous fluid by means of metals, evolves in this proceſs hydrogen gas: This is eminently the caſe in the diſſolution of iron or zinc by dilute ſulphuric acid. The phoſphoric acid acts nearly in the ſame manner as the ſulphuric with metals.

XX. Nitric acid is not only decompoſed by ſeveral metals, but alſo admits the decompoſition of water at the ſame time. For this it ſuffices, that the metal diſſolved in it be extremely greedy of oxygen: Such is particularly tin. In this caſe, the hydrogen of the water, uniting with the azot of the nitric acid, forms ammoniac; for which reaſon theſe ſolutions afford no gas, and contain ammoniacal nitrat. Hence we underſtand how moſt ſolutions of the white metals in nitric acid evolve ammoniacal vapours in the injection of quicklime.

XXI. The muriatic acid, as it is incapable of being decompoſed by combuſtible bodies, of itſelf diſſolves few metallic ſubſtances. It attacks only ſuch metals as poſſeſs ſufficient avidity for oxygen to decompoſe water: Accordingly, during the diſſolution of metals in the muriatic acid, hydrogen gas is always evolved.

XXII. Not only is the muriatic acid incapable of being decompoſed by metals, but it alſo poſſeſſes the property of attracting oxygen from moſt metallic oxyds: in doing which it paſſes to the ſtate of oxygenated muriatic acid. To this ſtrong affinity for oxygen the muriatic acid owes its property of eaſily diſſolving metallic oxyds, on which account it is employed with ſucceſs for diſſolving the oxyd of iron, which other acids are unable to attack. If metallic oxyds be ſurcharged with oxygen when we diſſolve them in muriatic acid, an effervеſcence ariſes, becauſe a part of the acid flies off in the form of oxygenated muriatic acid gas. If the oxyds be only at the proper point of oxydation for uniting with this acid, they diſſolve in it without any movement or effervеſcence, as ſalt or ſugar will in water.

XXIII. The boracic and fluoric acids unite but feebly with metallic oxyds: They do not diſſolve pure metals, becauſe they are not decompoſable by them; but they enable water to oxydate ſuch of them as have moſt affinity for oxygen. It is the ſame with the carbonic acid, which unites well with moſt metallic oxyds, and is often found combined with them in their native ſtate.

XXIV. Metallic acids are eaſily decompoſed by very combuſtible metals: They unite very perfectly with their oxyds, and are frequently found thus combined in a native ſtate.

XXV. Acids of the vegetable and animal kind, or of which the radicals are formed by hydrogen and carbon, are not decompoſed by metals; but they render water extremely decompoſable by them, and unite with metallic oxyds with conſiderable ſolidity. Many of them occaſion theſe oxyds to revert to the metallic ſtate.

XXVI. The oxyds of metals cannot unite with acids, and ſtill leſs remain combined with them, unleſs they contain certain proportions of oxygen: If they have leſs than the determinate quantity, no union will take place; if more, they will ſeparate from them.

XXVII. Beſide this general truth, there is another of the ſame kind peculiar to each acid and each metal; which is, that they cannot remain reciprocally united, but within certain limits of oxydation, and theſe oftentimes very confined. There is a determinate proportion of oxygen in the combination of an acid with a metallic oxyd.

XXVIII. It is in conſequence of this law, that metallic ſolutions expoſed to the air grow turbid, and form a precipitate, in proportion as the metallic oxyd, by abſorbing oxygen from the atmoſphere, becomes gradually inſoluble in the acid. This is the reaſon of the decompoſition, which the atmoſphere effects on moſt metallic ſulphats and nitrats.

XXIX. It even frequently happens, that metallic oxyds diſſolved in acids react by degrees on theſe ſalts, and take from them, though in cloſe veſſels and without the contact of air, a portion of their oxygen, ſo that they ſoon ſeparate, and are precipitated to the bottom of the ſolution.

XXX. Heat is eminently favourable to this ſucceſſive decompoſition of acids by metallic oxyds. Thus nitric ſolutions, when heated, grow turbid, or become more and more decompoſable by air and water, which is particularly remarkable in the nitric ſolution of mercury.

XXXI. There are metals which have ſo great tendency to oxydate themſelves with acids, that they cannot remain united, or form permanent ſolutions with them. This is particularly the caſe with thoſe, which have the property of becominga cids, or forming oxyds capable of combining with alkalis; as arſenic, tungſten, molybdena, antimony, tin, iron, &c.; accordingly we find the ſolutions of theſe metals, eſpecially in the nitric acid, are always loaded with precipitates, and contain little or no metallic oxyd.

XXXII. From what has been ſaid it appears, that, to form metallic ſalts, the oxyds of metals muſt remain united with acids, and have no tendency to ſeparate from them. It is requiſite too, that we do not augment their affinity for oxygen, or bring them into contact with this principle.

XXXIII. Metallic compound ſalts have always, or almoſt always, an exceſs of acid: All of them likewiſe are more or leſs acrid or corroſive, which ſhows a tendency to become acid in moſt metallic oxyds.

XXXIV. Thoſe properties of metallic ſalts with which it is of importance to be acquainted, may be included under the following heads.

1. Figure, and its varieties: 2. Sapidity or cauſticity, more or leſs powerful: 3. Alteration by means of light: 4. Fuſion, deſiccation, decompoſition, by means of caloric, more or leſs marked: 5. Deliqueſcence, effloreſcence, or decompoſition, more or leſs complete, by the action of the air: 6. Solubility in water, warm or cold; decompoſition more or leſs promoted by pure water &c.: 7. Decompoſition by earths and alkalis; nature of the metallic oxyds precipitated; complete precipitation, or formation of triple ſalts, partly alkaline or earthy, partly metallic: 8. Alteration of the metallic oxyds precipitated, at the inſtant of their precipitation, either by the air, or by the nature of the alkali employed for the precipitation, as happens when ammoniac is uſed: 9. Reciprocal alteration by different acids; decompoſition taking place, or not; affinity of acids for the metallic oxyds; changes of the oxyds diſcoverable by their colour: 10. Alteration by earthy or alkaline neutral ſalts, whether exhibiting an union without decompoſition, or a double decompoſition: 11. Reciprocal action of metallic ſalts on each other, announcing either ſimple union, a ſimple change of baſes by the acids, or a diſplacement of oxygen precipitating both the oxyds, one becauſe it is partly diſoxydated, the other becauſe it is ſuperoxydated, as is the caſe, for example, in the uſeful precipitation of the muriatic ſolution of gold by the muriatic ſolution of tin, which furniſhes the purple precipitate of Caſſius: 12. Union with earthy or alkaline ſulphures; the formation of a kind of a ſulphurous ores.

XXXV. Metallic oxyds have different degrees of affinity with acids, and ſome may be employed to decompoſe combinations of others. But the different affinities of metals for oxygen are the moſt important cauſe of the phenomenon of the precipitation of metallic ſolutions. Thus ſeveral metals, by taking oxygen from others diſſolved in acids, occaſion their reappearance in the metallic form; as mercury does with ſilver, copper with mercury, iron wth copper, zinc with iron, &c. Sometimes metals do not deprive metallic oxyds diſſolved in acids of all their oxygen; which occurs when the precipitating metal has no occaſion for all the oxygen of the metal diſſolved, to aſſume its place in the acid: Thus tin, when it precipitates the oxyd of gold, does not elicit from it all the oxygen it contains, but ſuffers it to precipitate in a peculiar ſtate of oxydation. Metallic oxyds, in dividing oxygen among them in new proportions, precipitate with properties which deſerve to be more accurately inveſtigated than has hitherto been done.

Application of what has been ſaid in this Chapter.

The preparation of all the metallic oxyds uſeful in the arts.
Coloured glaſs, enamels.
Metallic ſalts of uſe in the arts.
The effects of theſe ſalts in the arts in which they are employed.
The ſolution and parting of metals,
The precipitation of metallic oxyds by alkalis and earth.

Theſe applications are in general ſo uſeful and multifarious, that they cannot be exhibited unleſs in the particular hiſtory of each metal.

CHAPTER X.

THE FORMATION AND NATURE OF VEGETABLE SUBSTANCES.

I. THE ſubſtances which conſtitute the texture of vegetables differ from mineral ſubſtances in this, that they are of a more complex order of compoſition, and though all are extremely ſuſceptible of decompoſition or analyſis, not one is an object of ſyntheſis.

II. Nothing but the texture of living vegetables, nothing but their vegetating organs, can form the matters extracted from them; and no inſtrument invented by art can imitate the compoſitions, which are formed in the organic machines of plants.

III. Though vegetables form all the the materials which conſtitute their texture with four or five natural ſubſtances, caloric, light, water, air, and the carbon derived from ſome remains of plants decayed into mould, we find an extreme variety in the properties of theſe materials. Theſe may be reduced, however, to a certain number of principal heads, under the name of *immediate materials of plants*, becauſe they are obtained from them by ſimple proceſſes, almoſt wholly mechanical, by a ſort of direct analyſis, which does not alter their nature.

IV. Theſe matters, which are more or leſs compound, are placed in particular organs, veſſels, diſtinct cells, &c. Sometimes their ſeat is in the root, or ſtalk, bark, and leaves, at the ſame time: At others they are contained only in the flowers, fruits, or ſeeds, and even in certain parts of theſe organs. This particular ſituation of the immediate materials indicates the different organization of the texture of the part, as the cauſe of the various nature diſplayed by each of them

V. The different place occupied by each of theſe materials of vegetables often enables us to obtain them eaſily ſeparate and pure. It is ſufficient, when this local diſtribution occurs, to bruiſe and open the veſſels or cells which contain them, and expreſs their liquid juices. Nature herſelf frequently exhibits this ſeparation at the ſurfaces of plants, even by the power of vegetation: Thus the ſap, manna, gum, reſin, &c. ſpontaneouſly flow; though art is often obliged to ſeparate from each other ſeveral of theſe materials united and confounded together. The means it employs for this purpoſe are uſually ſimple and eaſily practiſed; ſuch as reſt, filtration, expreſſion, ablution, and diſtillation with a gentle heat, which produce no alteration in the ſubſtances ſubjected to theſe proceſſes.

VI. Among the materials of vegetable bodies obtainable by ſimple means, which change not their nature, may be reckoned the following ſubſtances, either fluid or ſolid:

1. The extractive matter, or extract.
2. Mucus, or mucilage.
3. Sugar.

4. Eſſential ſalts.
5. Fixed oil.
6. Volatile oil.
7. Aroma.
8. Camphor.
9. Reſin.
10. Balſam.
11. Gum-reſin.
12. Fecula.
13. Gluten.
14. Colouring matter.
15. Elaſtic gum.
16. The ligneous part.

Beſide theſe ſixteen principles, a ſubſtance analogous to animal albumen has been diſcovered in the analyſis of vegetables; and it is probable, that ſome other unknown vegetable principles exiſt, as the matter proper for tanning hides, or *tannin*, &c.

VII. It is neceſſary here to be fully aware, that, on reducing all the facts of vegetable analyſis to general terms, or leading reſults, nothing more has been found in any of the plants hitherto examined, than the eighteen ſubſtances abovementioned; ſo that we may affirm, that they actually compoſe the texture of all known vegetables, and that a very accurate analyſis is made of a vegetable, when we ſeparate theſe from it. Yet it is not to be underſtood, that all theſe eighteen immediate materials are to be found in the different parts of vegetables, or even in each vegetable taken all together. There are plants, all the parts of which do not furniſh ſo many as five or ſix of theſe materials: Others contain eight or ten; ſome afford them all. But ſuppoſing we could mingle and blend together, even chemically, all the plants which have ever occupied the attention of the chemiſt, this mixture, this combination, confuſed in appearance, would exhibit only the ſixteen or eighteen above mentioned ſubſtances, as the reſults of the moſt accurate and refined analyſis; whence we are juſtified in ſaying, that vegetables are formed of theſe immediate materials.

VIII. Each of the materials above announced has peculiar diſtinguiſhing properties, among which thoſe that can mark its characters, and render it eaſily diſcernible from the reſt, ſhould be ſelected. It is by no means impoſſible to treat this ſubject after the manner of botaniſts, and to have but one characteriſtic or ſpecific phraſe for each of theſe materials: And though this method has never yet been propoſed or executed in chemiſtry, I ſhall endeavour to preſent a ſketch of it in the ſucceeding ſections, as I have already done with reſpect to acids and compound ſalts.

Characters of the immediate materials of Vegetables.

IX. Extractive matter, or extract: Dry; brown; a little deliqueſcent; ſoluble in water; obtained from the juices of vegetables by inſpiſſation, or from decoctions or infuſions of them by evaporation; affording by diſtillation an acid, a little ammoniac, and ſome oil; abſorbing oxygen from the atmoſphere, and by this abſorption becoming gradually inſoluble; erroneouſly conſidered as a native ſoap; compoſed of carbon, hydrogen, azot, and oxygen, and always tending to abſorb more of the laſt than it contains in its primitive ſtate.

X. Mucus, or mucilage: An agglutinative, viſcous, inſipid ſubſtance; affording much pyromucous acid on diſtillation; ſoluble in both warm and cold water; abſorbing no oxygen from the atmoſphere; drying and becoming brittle in the form of gum; exiſting in roots, young ſtalks, and leaves; iſſuing from the bark of trees by expreſſion; gluing their fibres together.

XI. Sugar: Sapid and agreeable to the taſte; cryſtallizable, ſoluble, and fermentable; in moſt circumſtances reſembling mucilage, but differing from it in the property of fermenting and forming alcohol. Both mucilage and ſugar are compounds of carbon, hydrogen, and oxygen; differing from extract, 1ſt, By poſſeſſing a ſmaller proportion of hydrogen, on which account they do not abſorb, like extract, the oxygen of the atmoſphere; 2dly, By the abſence of azot, whence they afford no ammoniac on diſtillation.

XII. Essential salt: Comprehending the vegetable acids, formed in general of hydrogen and carbon more oxygenated than in the three preceding principles: Accordingly theſe are convertible into acids by the addition of oxygen. Vegetable acids, however numerous they may be, appear to differ only in the proportion of their three principles: They are all decompoſable by fire, capable of being converted into each other, and, on an ultimate analyſis, are reducible to water and carbonic acid by the addition of oxygen. See Chap. VII.

XIII. Fixed oil: Formerly called *groſs* or *expreſſed oil;* thick, ſweet, inodorous; burning when volatilized; forming ſoap with cauſtic alkalis; mixed with a mucilage named the ſweet principle of oils by Scheele; inſpiſſating and becoming concrete by the contact of air and abſorption of oxygen; experiencing the ſame effects by the action of acids and metallic oxyds; compoſed of carbon, hydrogen, and a little oxygen. It differs from the preceding compounds in containing a larger proportion of hydrogen; whence ariſe its combuſtibility, and its property of being converted into water and carbonic acid, when it burns with a ſufficient quantity of air, as it does in the hollow wicks ſurrounded on all ſides with air, which conſtitute Argand's lamp.

XIV. Volatile oil: Heretofore named *eſſential oil,* or *eſſence:* Highly acrid, highly odoriferous; entirely reducible to vapour at a heat of 184°; combining difficultly with alkalis; capable of being ſet on fire by acids; inſpiſſating to a reſin by the action of oxygen; burning more rapidly, and affording more water than fixed oil, and admitting more ſpeedily the precipitation of its charcoal, which forms lamp-black.

XV. Aroma: Formerly called *ſpiritus rector:* A very volatile principle, reducible to vapour by the ordinary heat of the air, and forming an atmoſphere round plants; paſſing over with water in diſtillation in *balneo Mariæ;* ſometimes of an inflammable nature, at others diſplaying ſaline properties, uniting with alcohol, fixed oils, vinegar, &c.; forming by theſe combinations what are called in pharmacy diſtilled waters; contributing by its preſence to the quantity of volatile oil diſtilled from plants, and bearing ſo great analogy to it, that they have been confounded together. The nature of aroma is not accurately known; ſome begin to ſuſpect, that it is not a diſtinct body, a ſingle principle diſengaged from vegetable matters, but theſe matters themſelves in ſubſtance reduced to a ſtate of vapour.

XVI. Camphor: A matter now recogniſed in a number of vegetables, and claiming to be reckoned among their immediate principles; of a concrete and cryſtalline form; very volatile; burning with the emiſſion of ſmoke; ſoluble in a large quantity of water, in alcohol, and in ether; exiſting in ſeveral volatile oils; contained pure in the trunk and leaves of the ſpecies of laurel which furniſhes it; too little known yet with regard to its intimate nature; yielding a peculiar acid by means of the nitric

XVII. Resin: A ſoft or dry ſubſtance; little odorous; combuſtible; ſoluble in alcohol, but not in water; uniting difficultly with alkalis; little alterable by acids; originating from inſpiſſated volatile oil, and appearing to differ from it only by a larger portion of oxygen.

XVIII. Balsam: Reſin united with benzoic acid; more odoriferous than pure reſin; affording its acid in a concrete ſtate by the agency of fire and water; yielding it to alkalis or earths; and approaching to reſin after having loſt its acid.

XIX. Gum-resin: A concrete juice; partly ſoluble in water, and forming with it a kind of emulſion, as it does with vinegar, which has been ſuppoſed its univerſal menſtruum, but ſtill more ſoluble in alcohol; not exuding naturally from vegetables like reſin, but extracted from their ruptured veſſels, in the form of a white or coloured juice, of a fetid ſmell more or leſs reſembling garlic.

XX. Fecula: A pulverulent, dry, white, inſipid, combuſtible matter; affording much pyromucous acid on diſtillation; ſoluble in boiling water, and forming a jelly with this liquid; convertible into the oxalic and malic acids by means of nitric acid; exiſting in all the white and brittle parts of vegetables, particularly in tuberoſe roots and gramineous ſeeds; conſtituting the baſe of the nouriſhment of animals, and diſpoſed to become readily a principle of their bodies.

XXI. Gluten: An elaſtic, ductile body, as if fibrous or membraneous; inſoluble in water; ſlightly ſoluble in alcohol; affording a conſiderable quantity of ammoniac on diſtillation; putreſcible like animal matter; turning yellow like it on the contact of nitric acid; convertible by this acid into oxalic acid; occaſioning the difference between the farina of wheat and other farinaceous ſubſtances, and beſtowing on it the capability of being made into a paſte.

XXII. Colouring matter: Always attached to one or other of the preceding materials; appearing variable in its nature; ſometimes ſoluble in water; at others, attackable only by alkalis, oils, or alcohol; indebted for the diverſity of its properties to the different quantities of oxygen fixed in it; poſſeſſing an affinity of attraction for alumin, oxyd of tin, &c.; and capable of combining more or leſs intimately with the textures of vegetables and animals.

XXIII. Elastic gum: Analogous to gum-reſin; appearing to exiſt in ſeveral vegetables; remarkable for the extenſibility and elaſticity it retains after deſiccation; affording ammoniac when diſtilled; diffuſing a fetid ſmell when burned; having been at firſt in the form of a white milky fluid, and converted from that ſtate to an elaſtic ſolid, by the abſorption of atmoſpheric oxygen.

XXIV. The ligneous part, or wood: A matter too much neglected hitherto by chemiſts; conſtituting the ſolid baſis of all vegetables, but far more abundant in thoſe which are hard; erroneouſly conſidered as an earth; inſoluble in water; affording, on diſtillation, the peculiar acid called pyroligneous; containing a large quantity of carbon; paſſing to the ſtate of three or four acids by the action of the nitric; and appearing to be the laſt product of vegetation.

XXV. From what has been exhibited above reſpecting the immediate and known materials of vegetables, it follows, that they are all reducible, on an ultimate analyſis, to three or four principles, which are their primitive component parts; namely, hydrogen, carbon, oxygen, and, in many, azot; and that they differ from each other only in the various proportions of the elements from which they are formed. Now, if we inveſtigate, by ſimple calculation, the number of different compounds that may reſult from the union of three or four principles in every poſſible proportion, we ſhall find, that a much larger number might exiſt. But as each of the ternary or quaternary compoſitions which conſtitute the immediate materials of vegetables, admits, as far as it appears, a certain latitude of proportions, while retaining its general nature of extract, muſilage, oil, acid, reſin, &c., it is eaſy to conceive, that the different proportions of the principles included within theſe ſeveral latitudes, ſet bounds to the vaſt, immeaſurable variety of colour, ſmell, taſte, and conſiſtency, which are obſervable in all the materials of vegetables, and which men diſcern in ſuch of them as they employ in their food, garments, habitations, &c.

XXVI. On the ſame conſideration, it will not be more difficult to conceive, that vegetables muſt vary in the nature and ſpecific properties of their materials, according to the ſeveral periods of their vegetation; that they can never remain in the ſame ſtate; and that the different ſcenes exhibited in the periods of germination, leafing, bloſſoming, fructification, and maturity, which conſtitute vegetable life, muſt be accompanied and marked by internal change, as they are by external appearance. Of this the variouſly modified taſte, inceſſantly changing colour, ſmell not more ſtable, and difference of texture, which characterize the ſeveral epochs of vegetation, afford inconteſtible proofs.

XXVII. A new advantage ariſing from the preſent philoſophy of chemiſtry, is the having thus diſtinguiſhed the nature of the materials of plants, far more complex than that of mineral ſubſtances. The acquiſition of this knowledge, leads to an appreciation of the changes wrought in vegetable matters by different chemical agents. Thus, we can no longer profeſs ourſelves ignorant of the action of the deſtructive agent fire on vegetable ſubſtances. From the preceding conſiderations, are underſtood how, when a complete vegetable, or any one of its different products, is ſubjected to the action of fire, caloric tends to reduce theſe complicated compounds to more ſimple ones, by occaſioning the union of their principles, two and two together, in proportions very different from thoſe which before obtained. By gently heating them, the hydrogen is extricated, which burns alone, and much carbon remains: If they be ſtrongly heated, the carbon is diſengaged at the ſame time with the hydrogen, they both burn in the air, and the only reſiduum left, conſiſts of that ſmall quantity of earth and ſalts, which conſtitutes vegetable aſhes.

XXVIII. All the immediate materials of vegetables being reducible in their ultimate analyſis to three or four original principles, namely, hydrogen, carbon, oxygen, and a little azot in ſome of them; this analyſis, moreover, anſwering with the utmoſt preciſion to the manner in which vegetables are nouriſhed, grow, ſpread, and perpetuate their ſpecies, ſince we know that vegetation, to take place, requires only theſe ſimple principles; nothing more remains, but to find how plants appropriate theſe ſorts of elements, and combine them in their organic ſtrainers, to compoſe the different ſubſtances, the properties of which have been announced.

XXIX. It appears beyond all doubt, that water is the ſource whence vegetables derive their hydrogen; that they decompoſe this fluid in their leaves, by the help of the ſolar light, abſorb its hydrogen, which becomes fixed in them in the ſtate of oil, or extract, or mucilage, &c., and ſeparate its oxygen, a great part of which, being diſſolved in light and caloric, flies off in the ſtate of vital air. But a portion of the oxygen of the water is fixed at the ſame time in the texture of the vegetable, in which it is retained chiefly by the carbon.

XXX. It is not ſo eaſy to account for the carbon that exiſts in vegetables. Some natural philoſophers ſuppoſe, that vegetables decompoſe carbonic acid at the ſame time with water, and abſorb its carbon: But this ſuppoſition is not proved, though it has acquired ſtrength, ſince the decompoſition of carbonic acid, combined with ſoda, by means of phoſphorus, has been diſcovered. Other chemiſts are of opinion, that vegetable earths, mould, dung, and particularly the water of dunghills, furniſh the carbon, attenuate, and even diſſolved in water; that plants abſorb this principle by their roots; and that they do not extract it from carbonic acid. According to this hypotheſis, manure affords only carbon, and the water of it is nothing more than a ſaturated ſolution of this principle. To theſe data we muſt reſtrain at preſent the theory of vegetation.

Applications of the Reſults of the tenth Chapter.

The applications of the reſults delivered in this chapter are extremely multifarious; they relate to agriculture, rural economy, pharmacy, materia medica, and all the arts in which vegetable ſubſtances are employed. The following is a ſlight ſketch of the principal features of theſe important applications:

Germination.
The developement of leaves.
Bloſſoming.
Fructification.
The maturation of fruits and ſeeds.
The ſucceſſive formation of gum, extract, oil, reſin, ſalts, ſugar, the colouring matter, and wood, in the different periods of vegetable life.
The growth of the woody ſubſtance, bark, &c.
The pharmaceutical preparations of juices, extracts, eſſential ſalts, mucilages, oils, reſins, gum-reſins, aromatic waters, &c.
The arts of the ſugar-maker, confectioner, miller, baker, ſtarch-maker, vine-dreſſer, brewer, diſtiller, varniſher, dyer, paper-maker, indigo-maker, colour-man, flax-man, perfumer, oil-man, ſoap-boiler, maker of charcoal, &c.

CHAPTER XI.

OF THE FORMATION AND NATURE OF ANIMAL SUBSTANCES: THE THEORY OF ANIMALIZATION.

I. It is an eſtabliſhed truth, that, without the aid of vegetables, animals cannot ſupport their exiſtence: Accordingly it has long been ſaid in natural hiſtory, that vegetables are formed from minerals, and animals from vegetables. But if this truth have been long known, the mode in which theſe bodies are changed, or reciprocally converted into each other, has never yet been aſcertained. On this point, however, the labours of chemiſts ſhould be principally exerted: For, were this problem once ſolved, it would lead us to a preciſe knowledge of all that concerns the animal economy: And ſome reſults conducive to this grand inquiry are already afforded us by modern diſcoveries.

II. The moſt certain means of ſolving this important problem are unqueſtionably firſt to acquire an accurate knowledge of animal ſubſtances, to compare them with thoſe of the vegetable kingdom, and to inveſtigate with care their difference or analogy. There is no doubt, were theſe differences once well known, they would enable us to underſtand the cauſe from which they ariſe.

III. If we compare the reſults of all the modern analyſes made of the blood and humours, and of the ſolid parts which manifeſtly originate from the concretion of theſe, we ſhall find, that animal ſubſtances differ from vegetable ſubſtances in

A. The property of affording a conſiderable portion of ammoniac, and very fetid products, by the action of fire:

B. In that of putrefying more eaſily, and more ſpeedily, and giving out a far more noiſome ſmell:

C. In yielding, when acted upon by nitric acid, much more azotic gas: and

D. In contributing ſingularly to the formation of nitric acid.

IV. All theſe differences ſeem to depend only on the preſence of one principle in animals far more abundantly than in vegetables; which is azot. It may be ſaid, therefore, that the addition of azot to vegetable matters would ſuffice to convert them into animal ſubſtances.

V. Yet it is proper to obſerve, that to theſe primary differences, which may be termed *capital* ones, ſome other particular phenomena may be added, the influence of which, though undoubtedly inferior, on the animal compoſition, ought by no means to be neglected. Such, among others, is the preſence of phoſphoric acid, and the different phoſphats, particularly thoſe of ſoda, lime, and ammoniac, in the animal humours. To theſe ſalts are owing the peculiar quality of the coal of animal ſubſtances, eſpecially its being almoſt incombuſtible.

VI. The peculiar principle, which is ſo abundant in theſe ſubſtances, and more eſpecially renders them different from vegetable matter, azot, appears, then, to be the efficient cauſe of the properties which diſtinguiſh them, and particularly of that ſort of concreſcibility, or plaſticity, which will ſoon be conſidered more at large. It may be affirmed, therefore, that, if we were to deprive animal ſubſtances of azot, they would become again in ſome meaſure vegetables; as, to convert the latter into animal ſubſtances, it is ſufficient to combine with them, or introduce into them, azot.

VII. Thus all the matters which form the bodies of animals may be conſidered as ſo many immediate principles, as was done in the preceding chapter with regard to vegetables. In the ſame manner each of theſe principles ought to be characterized by the enumeration of its moſt ſtriking properties. If we ſo examine and deſcribe the blood, milk, bile, fat, urine, &c., and the ſolids of animals, we ſhall obtain a comparative ſcale, which will exhibit the relations and differences that form the object of our ſearch.

VIII. Blood: A red fluid; warm at a temperature of 93° in man, quadrupeds, and birds; at the temperature of the medium they inhabit in oviparous quadrupeds, ſerpents, and fiſhes; ſweetiſh; coagulable by cold; miſcible with water; ſeparating almoſt ſpontaneouſly into three different ſubſtances, white ſerum, red ſerum, or the colouring part, and fibrous matter; exhibiting in each of theſe ſubſtances diſtinguiſhing characters, namely, in the ſerum, alkalinity, coagulability by fire, metallic oxyds, &c., coagulability owing to the more intimate combination of oxygen; the ſame general nature in the red ſerum, which differs from the white only in the preſence of oxyd of iron; in the fibrous matter, or fibrin, ſpontaneous concreſcibility, and ſolubility in alkalis.

Theſe principal characters ought to be conſidered in the whole of the blood, which appears to be the primary principle of all animal ſubſtances, the common origin of all the humours and of all the ſolids. It has been called fluid fleſh, in conſequence of the fibrin, which concretes in it on cooling. The cauſe of its heat has been diſcovered in the alteration and abſorption of vital air in reſpiration: And the renovation of the blood by the chyle, and the converſion of the chyle into animal matter, have in like manner been found to originate from the extrication of a conſiderable quantity of carbon and hydrogen, which appears to take place in the lungs.

IX. Milk: A white fluid, bland and ſaccharine, formed of ſerum, cheeſe, and butter, intimately mixed, and exhibiting a true animal emulſion. In the ſerum of milk we ſhould particularly notice the ſubſtance called ſugar of milk, which may be ſaid to have the character only of an incipient ſugar, and the quantity of phoſphat of lime, more abundant than in the other humours, which ſeems to indicate, that nature thought fit to place in the firſt nouriſhment of animals a quantity of oſſeous baſe, with a view to the neceſſary celerity of the formation and growth of the bones in the earlieſt ſtage of their lives. The cheeſe is a true albuminous matter. The butter is a concrete oil, the ſolidity of which, and its eaſy ſeparation from the milk by ſimple agitation, appear owing to the abſorption of atmoſpheric oxygen during the formation of the cream.

X. Bile: an oily ſaponaceous fluid; compoſed of an oil approaching the ſtate of ſpermaceti and ſoda, mingled with albuminous fluid; formed in the liver, a viſcus which itſelf contains a large quantity of oil. In the ſyſtem of the voluminous gland juſt mentioned, every thing indicates a diſpoſition, an organization, deſigned to ſeparate from the blood the large portion of fat, which ariſes from the retardation of this fluid in the venous ſyſtem of the abdomen. This conſideration, deſtined ſome day to become one of the principal baſis of the phyſiology hinted at above, accounts for the bulk of the liver in the fœtus which has not breathed, as well as in animals which have no reſpiratory organ ſimilar to thoſe of man, birds, and quadrupeds. It alſo explains the origin of ſome diſeaſes of the liver, particularly of its concretions or gall ſtones.

XI. Fat: A ſort of oily matter; formed at the extremities of the arteries, and as far as may be from the centre of motion and animal heat; affording a kind of reſervoir, in which that large quantity of hydrogen which could not be evacuated by the lungs becomes fixed; an oil united to a conſiderable portion of oxygen, and containing beſides ſebacic acid. This manner of conſidering fat, is one of the moſt ſtriking points of modern phyſics as it regards animals.

XII. Urine: An excrementitious fluid; more or leſs coloured, acrid, and ſaline; remarkable for the large quantity of free phoſphoric acid, and phoſphat of ſoda, ammoniac, and lime, which it contains, and ſtill more ſo for the preſence of a peculiar acid not yet found in any other animal humours, which is now called the lithic, becauſe it forms the baſis of the ſtones of the kidneys and bladder, which cauſe the diſeaſe known by the name of lithiaſis.

Urine has been the ſource of diſcoveries highly valuable to the chemiſt, and muſt be of others ſtill more valuable to the phyſician. Conſidering it firſt as a lixivium, deſigned to carry out of the body a large quantity of ſaline matters, which would injure the due exerciſe of its functions, we muſt not forget that it is an evacuation, the proportion of the principles of which, varying according to the ſtate of the body, becomes a kind of ſtandard to ſhow the modifications of the body, in health or ſickneſs, by a ſeries of obſervations, which phyſicians have already commenced under fortunate auſpices. We ſhould conſider it, too, as always containing the matter of renal and veſical concretions, which ſeem to require for their formation only a little longer reſidence in the reſpective organs than nature intended, or the preſence of a nucleus, which attracts, in ſome meaſure, the ſucceſſive lithic ſtrata. We muſt alſo obſerve the proportions of the different principles in the urine, particularly of the uncombined acids it contains, and the phoſphat of lime which it carries along with it; for theſe, differing remarkably in diſeaſes of the joints, the aponeuroſes, and the bones, will at ſome future period become, in the hands of ſkilful obſervers, new means of diſcovering the nature of theſe complaints, aſcertaining their progreſs, and perhaps inſuring their cure.

XIII. Little can be ſaid here of the other animal fluids, ſuch as the inſenſible perſpiration, ſweat, the gaſtric juice, ſaliva, tears, the mucus of the noſe, the cerumen, the ſeminal liquor, &c.,

becauſe none of theſe fluids have yet been much examined. All have unqueſtionably their peculiar compoſition, and differ in ſome points, particularly in the proportion of their principles. Some of theſe humours, with which modern experiments have rendered us a little better acquainted, exhibit the union of a peculiar mucilage with water, pure ſoda, phoſphat of lime, and phoſphat of ſoda: Such are the tears, the naſal mucus, and the ſpermatic fluid. Of theſe the firſt and ſecond diſplay likewiſe the property of inſpiſſating by the contact of the air and the abſorption of oxygen, which probably conſtitutes the maturity, as it is called, of the humours in catarrh, whether it be confined to the noſe and fauces, or extend to the lungs. The ſeminal liquor has offered us the ſingular phenomenon of the cryſtallization of phoſphat of lime, which was never before known.

XIV. On conſidering the whole of the ſolid matters which compoſe the various textures of the different organs of animals, the ſubſtances of which they are formed may be divided into three principal genera: The firſt comprehends the albumen; the ſecond, the gelatin, or gelatinous matter; the third, the fibrin, or fibrous matter: Two of theſe have already been diſtinguiſhed under the article of blood, in the eighth ſection of this chapter. I ſhall do no more here than give a conciſe ſketch of the conſtant phenomena, which may be conſidered as the characters of each of theſe genera.

GENUS I.

Albumen: Coagulable by heat, acids, oxyds, and in general by oxygen in a concrete or nearly concrete ſtate; ſoluble by alkalis; found more or leſs condenſed or oxygenated, and interwoven in the membranes, tendons, cartilages, and, in general, all the white parts of animals.

GENUS II.

Gelatin: Participating the ſolidity of the firſt in moſt of the white organs, but capable of being ſeparated from it, and eaſily diſſolved by boiling water, to which it gives the form of a jelly on cooling. As it conſtitutes the baſe, or principal part, of all the white organs in general, theſe are more or leſs completely ſoluble in boiling water, and form tranſparent jellies by the refrigeration of theſe ſolutions.

GENUS III.

Fibrin: Inſoluble in water, at any temperature; ſoluble in acids; containing a large quantity of azot; condenſed, concrete, and organized, in muſcular fleſh, which may be regarded as the proper receptacle of all the fibrin contained in the blood: Accordingly, conſidering the muſcles as the ſecretory organs of the fibrous matter of the blood, we ought to inveſtigate all its modifications, with reſpect to the quantity or proportion which fixes in theſe organs, and more particularly with regard to their apparent excluſion of it under various circumſtances of diſeaſe, old age, &c.

XV. Theſe three matters, albumen, gelatin, and fibrin, in a ſtate of concretion, of combinations of two and two, or all three together, and eſpecially in different proportions, form all the ſolids of animals, and are ſeparable from each other by a ſimple and eaſy analyſis: They alſo, particularly the albumen, form many of the fluids of animals; only in theſe they contain leſs oxygen, more water, and are combined with acids, neutral ſalts, &c. It muſt be obſerved, that in the fluids, the gelatin is as deficient as in the ſolids it is abundant, appearing to acquire its nature of gelatin in paſſing from the fluids to the ſolids. Albumen diſſolved in acids by art aſſumes properties analogous to thoſe of gelatin.

XVI. The ſolid animal matter, or bony ſubſtance, is of another order of compoſition. A large quantity of an earthy ſalt, almoſt wholly inſoluble, phoſphat of lime, is amaſſed in the texture or primitive parenchyma of the bones. This is the whole myſtery of the ſtructure and compoſition of this part of the animal frame; and for this reaſon bones yield jelly on being boiled in water, and a conſiderable quantity of oil and ammoniac on diſtillation; and when thoroughly calcined, or burnt, they are nothing more than calcareous phoſphat, mingled with ſome ſmall portion of carbonat, muriat, and phoſphat of ſoda.

XVII. When any one of the preceding animal matters, particularly of the condenſed white fluids, or white organs, is treated with nitric acid, there will be extricated a more or leſs conſiderable quantity of azotic gas, and of pruſſic acid gas, which appears to be nothing but a combination of azot, hydrogen, and carbon, with a little oxygen. Gelatin yields the leaſt, albumen ſomewhat more, and fibrin the moſt. In proportion as this change of combinations in the principles of animal matters is effected by means of the nitric acid, they ſeem to revert to their ancient ſtate of vegetable matter, from which they do not eſſentially differ, as has already been ſaid, but by the preſence of azot, their proportion of carbon and hydrogen not being the ſame, and greater complication in the number of principles, from a combination of which they are formed. Thus inſtead of being ternary compounds, as vegetable ſubſtances are, animal matters are quaternary compounds, and even ſtill more complicated. Azot is the fourth primitive principle, which is ſuperadded to hydrogen, carbon, and oxygen.

XVIII. Accordingly, the converſion of vegetable into animal matter, which conſiſts only in the fixation or addition of azot, muſt be conſidered as the principal phenomenon of animalization: This alone explains its chief myſteries; and when once we are perfectly acquainted with the mechaniſm of this addition of azot, moſt of the functions of the animal economy, which effect it, or depend on it, will become equally known.

XIX. What we already know of the ſubject is confined to the following conſiderations. The phenomenon is not ſo much owing to the fixation of a new quantity of azot, as to the ſubtraction of other principles, which increaſe its proportion. In reſpiration, the blood exhales a large quantity of hydrogen, and of carbon, either ſimply diſſolved in hydrogen gas, or converted into the ſtate of carbonic acid by the very act of circulation, and in the vaſcular ſyſtem, according to ſome modern philoſophers. In the cavities of the bronchia, during the act of reſpiration, and by the inſtrumentality of this act, the hydrogen forms water, which exhales in expiration. A portion of oxygen appears at the ſame time to become fixed in the pulmonary blood, and, circulating with this fluid through the veſſels, gradually combines with the carbon, ſo as to form that carbonic acid, which is extricated from the venous blood in the lungs. It is eaſy to conceive, that, by thus diſengaging a large quantity of hydrogen and carbon, reſpiration muſt neceſſarily augment the proportion of azot. The ſtudy of the mechaniſm of the other functions, which remains to be purſued, will undoubtedly lead to new diſcoveries, ſtill more important than the preceding: What has been performed within a few years naturally prompts us to imagine, that ſtill more will be done. The analogy of action which has been diſcovered between digeſtion, reſpiration, circulation, and inſenſible perſpiration, has begun to eſtabliſh on new views, more ſolid than were heretofore poſſeſſed, a ſyſtem of animal phyſics, which promiſes an abundant harveſt of diſcoveries and improvements. Unqueſtionably it will be in purſuing the phenomena of digeſtion and growth in young animals, that an edifice equally novel and ſolid will be erected on theſe foundations. Every thing is ready for this grand work; ſeveral philoſophers purſue this unbeaten path of experience; freſh ardour, ſpringing from theſe new conceptions, animates thoſe who are engaged in this branch of phyſics; and the track they have juſt begun to explore appears ſuch as muſt lead them to more preciſe and accurate reſults, than any that have hitherto been advanced on the functions which conſtitute animal life.

Applications of the Articles in this Chapter.

The functions of the animal economy, particularly
Reſpiration;
Digeſtion;
Hematoſis, or ſanguification;
Inſenſible perſpiration;
The ſecretion of the bile;
Oſſification and oſteogony; and
Nutrition.
The diſeaſes dependent on the degeneration of the humours, &c.
Animal concretions.
The action of various medicines on the humours, &c.
The arts employed in the manufacturing of animal matters, particularly thoſe of the tanner, currier, preparers of different kinds of glue and ſize, makers of catgut, thoſe who extract oils, and thoſe who work on horn, bone, tortoiſeſhell, &c.

CHAPTER XII.

OF THE SPONTANEOUS DESTRUCTION OF VEGETABLE AND ANIMAL SUBSTANCES.

I. WHEN vegetables and animals are deprived of life, or when their products are removed from the individuals of which they made a part, movements are excited in them, which deſtroy their texture, and alter their compoſition. Theſe movements conſtitute the different kinds of fermentation. The intention of nature in exciting them is evidently, to render more ſimple the compounds formed by vegetation and animalization, and to cauſe them to enter into new combinations of different kinds. When a portion of matter has been employed for ſome time in the fabrication of an animal or vegetable body, it muſt be rendered up by it to form new compoſitions, as ſoon as the functions of the body are at an end.

II. From the general definition of fermentation it would ſeem that there ought to be as many peculiar and different fermentations, as there are vegetable and animal matters to be changed and decompoſed: but ſeveral of them purſuing a ſimilar path to arrive at a more ſimple ſtate of compoſition, the number of fermentations has been reduced to three, the vinous, acetous, and putrid.

III. Vinous fermentation, as its name imports, is that which produces wine or alcohol. The ſaccharine matter is the only one which undergoes this fermentation, when diluted with a certain quantity of water, and mingled with a third ſubſtance of ſome kind, vegetable or animal, as extract, ſalt, fecula, or the like: For it is now fully proved, that ſugar and water alone never enter into vinous fermentation. The ſaccharine matter is ſo abundant and generally diffuſed through vegetable and even animal ſubſtances, that there are a great number of bodies capable of affording wine, or yielding alcohol. All ſweet and ſaccharine fruits reduced to a pulp, and more eſpecially their expreſſed juices, undergo a movement, when they are at a temperature of 62° or upwards, if they be in a large body, and particularly when neither too thick nor too thin. Hence the great number of different wines, comprehending the decoctions of grain malted, and by this proceſs converted in part into ſaccharine matter, and even the vinous liquors made with milk, honey, blood, &c.

IV. Vinous fermentation announces itſelf in ſaccharine liquors by an increaſe of volume, the formation of a copious ſcum which cover their ſurface, riſe of temperature, the diſengagement of a conſiderable quantity of carbonic acid gas, and the converſion of a ſweet fluid into a ſharp, warm, and pungent, liquor.

V. The cauſe of this fermentation appears to be owing to a decompoſition of water, a great part of the oxygen of which, attacking the carbon of the ſugar, burns it, and converts it into carbonic acid. At the ſame time the hydrogen of the water attacks the ſugar diveſted of its carbon, and, combining with it, gives birth to alcohol. Thus alcohol may be defined to be ſugar minus a certain quantity of carbon, and plus a certain portion of hydrogen. This theory explains both the formation of the carbonic acid evolved during the progreſs of vinous fermentation, and that of the alcohol, as well as all the properties of this new production.

VI. Pure alcohol is a white liquid, of a ſtrong ſmell, of a hot and acrid taſte; riſing in vapour at a temperature of 150°; inflammable at any temperature; affording much water and carbonic acid in burning; yielding no ſmoke in combuſtion; miſcible with water in any proportion, and expelling its air and a part of its caloric while combining with it; diſſolving pure or cauſtic alkalis; decompoſing acids, and convertible into ether by this decompoſition; diſſolving deliqueſcent neutral ſalts, and ſeveral metallic ones; taking from vegetables their volatile oil, aroma, reſin, balſam, part of their gum-reſin, and many colouring matters: Finally, of uſe in various proceſſes of the arts, in conſequence of theſe ſeveral properties.

VII. The reader may have already remarked, that the formation of alcohol takes place at the expence of the deſtruction of a vegetable principle, and that the ſaccharine matter undergoes a decompoſition, which reduces it to a more ſimple term; thus vinous or ſpiritous fermentation is a commencement of the deſtruction of principles formed by vegetation: And thus it may be regarded as one of the movements eſtabliſhed by nature, to ſimplify the order of compoſition, which vegetable ſubſtances exhibit.

VIII. The acid or acetous fermentation is the ſecond natural movement, which contributes to reduce vegetable compounds to more ſimple ſtates of compoſition. This fermentation, which produces vinegar, takes place only in liquors that have previouſly undergone the vinous fermentation. It has been obſerved, that the contact of air is neceſſary to the production of vinegar: It has even been perceived, that wine in turning ſour abſorbs air; ſo that a certain portion of the oxygen of the atmoſphere appears to be neceſſary to the formation of the acetous acid.

IX. Unqueſtionably there are ſeveral other fermentations analogous to that which forms vinegar, though their products are not yet well known, ſuch for inſtance are that of water mixed with ſtarch, called ſtarch-makers ſour water, and thoſe which form ſour bread, ſour kraut, and ſour liquours. All theſe changes are to be conſidered as means of decompoſition for ſimplifying the complex combinations of vegetables.

X. Finally, after vegetable liquors, or their ſolid parts moiſtened, have paſſed to the acid ſtate, their decompoſition, continuing under favourable circumſtances, namely a gentle or warm temperature, expoſure to air, and the contact of water, leads them into putrefaction, which terminates in volatilizing moſt of their principles under the form of gas. Water, carbonic acid, carbonated and even ſulphurated hydrogen gas, volatile oil in vapour, and ſometimes even azotic gas and ammoniac, are evolved; and after this there remains nothing but a brown or black reſiduum known by the name of mould, formed of carbon ſomewhat fat and oily, from which water ſtill extracts ſome ſaline ſubſtances and a little extractive matter.

XI. Nature, in organizing animals, and forming their fluids and ſolids by complex compoſitions, has placed in them a germ of deſtruction, which developes itſelf after the death of the individual.

This deſtruction is effected by the movement termed putrefaction, which conſiſts in a kind of fermentation, a ſlow decompoſition of the ſolid or fluid ſubſtances. Their order of compoſition, being more complex than that of vegetable matters, renders them ſtill more ſuſceptible of the putrid decompoſition.

XII. Animal ſubſtances compoſed of hydrogen, carbon, oxygen, and azot, and frequently ſtill more complicated by the union of ſulphur, phoſphorus, &c., when deprived of that movement, and more particularly of that renovation, which conſtitute animal life, are ſoon altered by more ſimple attractions between their principles, which have a tendency to unite two and two together. This reaction gives birth to binary compounds, ſuch as the carbonic acid, nitric acid, ammoniac, and carbonated hydrogen gas, which gradually eſcape into the atmoſphere, proportionably diminiſhing the quantity of animal matter. It is thus, in conſequence of a natural decompoſition, that we perceive this animal matter ſoften, change colour and ſmell, loſe its texture and form, and diffuſe through the atmoſphere vapours and gaſes, which diſſolve in the air and transfer to other bodies, particularly thoſe of vegetables, the materials neceſſary for their formation.

XIII. All the phenomena of the putrefaction of animal ſubſtances depend on the mechaniſm here explained. In the union of hydrogen and azot we perceive the formation of ammoniac, which has been deemed the principal offspring of putrefaction. The combination of carbon with oxygen explains the generation and evolution of carbonic acid, in which all the myſtery of putrefaction was made to conſiſt, about the time when gaſes were firſt diſcovered. Nitric acid, to the production of which it is well known how much animal ſubſtances contribute in artificial nitre-pits, ariſes from the union of oxygen with azot. A certain quantity of hydrogen gas is extricated, and carries off with it carbon, ſulphur, and even phoſphorus: Hence the various noiſome ſmells, and perhaps the phoſphoreſcence, of all putrefying animal matter.

XIV. When all theſe volatile principles have united two and two together, and diffuſed themſelves in the atmoſphere, nothing remains but a portion of carbon, combined or mingled with fixed ſaline ſubſtances, ſuch as the phoſphats of ſoda and of lime. Theſe reſidua form a ſort of mould termed *animal earth*, which frequently retains a little ſulphurated and carbonated hydrogen gas, fat, and extract, and in this vegetables find in abundance the principles requiſite for the formation of their materials. It is on this account, that the reſiduum of animal matter is ſo proper for manure, when ſufficiently concocted.

XV. A certain portion of water is neceſſary for this putrid decompoſition of animal ſubſtances: it furniſhes them with the quantity of oxygen neceſſary to the compoſition of carbonic and nitrid acids; and it contributes highly to the production of the putrefactive movement, by the attractions of the oxygen it introduces to them. It is equally indubitable, that the hydrogen ariſing from the decompoſition of this water, contributes greatly to the formation of ammoniac: For it is a well known fact, that, when animal matters are diluted with a large quantity of water, they furniſh abundance of ammoniac in their decompoſition.

XVI. Putrefaction, conſiſting in a ſeries of particular attractions, is modified in many different ways by external circumſtances, ſuch as temperature, the medium the animal ſubſtance occupies, the ſtate of the atmoſphere, whether more or leſs light or heavy, moiſt or dry, &c. Thus dead bodies buried in the earth, immerſed in water, or ſuſpended in the air, are differently affected; and moreover their bulk, their quantity, their propinquity to other bodies, and all the varying properties of the three mediums above enumerated, diverſify the effects produced.

XVII. We have proofs of this aſſertion, in what happens to bodies interred ſingly, and thoſe which are buried in numbers heaped on one another. The former, ſurrounded with a large quantity of earth, are ſoon deſtroyed by putrefaction; the aeriform or liquid products of which are abſorbed by this earthy maſs, or by the atmoſphere. The latter, not having around them this kind of earthy or atmoſpheric recipient, remain a long time without being deſtroyed; and the animal matter is wholly converted into ammoniac and concrete oil, which are known to form a ſoap ſimilar to that which is found in the ſoil of burying-places ſurcharged with dead.

XVIII. The phenomena attending the deſtruction of animal ſubſtances immerſed in water are likewiſe different. As new products are formed, the water diſſolves them, and tranſmits them to the air. Continual moiſture, with a conſtant temperature ſome degrees above 32°, favours the putrefaction of theſe ſubſtances, and their diſſolution into a ſtate of gas. On the contrary, a hot and dry air, volatilizing the water, deſiccates and hardens the bodies of animals, and preſerves them almoſt as well as the dry and burning ſand of Egypt, ſo abounding in natural mummies.

XIX. Though all the circumſtances of putrefaction, and the almoſt innumerable varieties of the phenomena they exhibit, are not yet deſcribed, or even known, we have diſcovered, that they are confined to the converſion of complex ſubſtances into ſubſtances leſs compound; that nature reſtores to new combinations the materials which ſhe had but lent, as it were, to vegetables and animals; and that ſhe thus accompliſhes the perpetual circle of compoſitions and decompoſitions, which atteſts her power, and demonſtrates her fecundity, while it announces equal grandeur and ſimplicity in the courſe of her operations.

Applications of the Propoſitions of the laſt Chapter.

Beſide the ſubjects mentioned at the end of the two preceding chapters, to which the articles of this almoſt directly apply, we find, in the ſeveral facts here enumerated, the following applications.

The preſervation of all ſubſtances extracted from vegetables.

The ſeveral ſpontaneous alterations they undergo, the acetous fermentation, the vinous, &c.

The products of theſe alterations, frequently employed for the purpoſes of the arts.

The production of ammoniac and nitric acid.

The influence of putrefaction in the different regions of living bodies.

The contagion and maladies produced by the effluvia of putrefied ſubſtances.

The theory of the ſituation and management of hoſpitals, drains, ſinks, layſtalls, cemeteries, &c.

ELEMENTS
OF
NATURAL HISTORY
AND OF
CHEMISTRY.

PART I.

GENERARL FACTS AND OBSERVATIONS.

CHAPTER I.

DEFINITION OF CHEMISTRY; METHODS OF PERFORMING OPERATIONS; ADVANTAGES DERIVED FROM THIS SCIENCE, &C.

CHEMISTS are not generally agreed on the moſt proper definition of chemiſtry. Boerhaave, in his Elements, ſeems to have ranked it among the arts; or, to ſpeak more accurately, he has defined only the practical part. Chemiſtry, according to Macquer, is a ſcience, whoſe object is to diſcover the nature and properties of all bodies, by their analyſis and combinations; and this definition is indiſputably the beſt that has yet been given. But as it is certain that analyſis and ſyntheſis cannot, with equal ſucceſs, be employed in all caſes where bodies are to be examined, would it not have been better to have omitted mentioning them in defining this ſcience? The chemiſt cannot arrive at the knowledge of the properties of bodies, but by bringing them into contact; and as the reſult is derived only from the mutual actions of bodies on each other, we think the following definition may be properly adopted: Chemiſtry is a ſcience which explains the intimate and reciprocal action of all bodies in nature on each other. The facts hereafter to be related, will illuſtrate this definition. To exhibit the extent of this ſcience with perſpicuity and order, we ſhall proceed to conſider the objects or ſubſtances to which its reſearches or operations are directed, the methods or means employed, and the advantages propoſed to be thence derived.

§ 1. *Concerning the object, the methods, and the intention of chemiſtry.*

The objects to which the attention of the chemiſt is directed, comprehend the whole of the ſubſtances that compoſe the globe we inhabit, whether buried in its interior parts, or found at its ſurface. Chemiſtry is, therefore, of equal extent with natural hiſtory, the ſame limits being common to both

Analyſis, or decompoſition, and ſyntheſis, or combination, are the two methods which chemiſtry uſes to accompliſh its purpoſes. The firſt is nothing more than the ſeparation of bodies, whoſe union formed a compound ſubſtance. Cinnabar, for example, is compoſed of ſulphur and mercury; the art of chemiſtry ſeparates the two, and by that means analyzes it. Till very lately it has been generally thought, and there are ſtill many perſons who retain the opinion, that this method is more advantageous in chemical reſearches than the other. This opinion had even acquired ſuch place in the minds of the learned, that many writers have defined chemiſtry to be the ſcience of analyſis. But nothing can be more contrary to the accurate and well founded idea or degree of eſtimation we ought to have of decompoſition. In order to ſhow this important truth in its proper light, it is neceſſary to diſtinguiſh two kinds of analyſis; the true, or ſimple; and the falſe, or complicated. We call that the true analyſis, by which the principles of a body are obtained, without having themſelves ſuffered any alteration. The only diſtinguiſhing criterion of this is, that by recombining them, a body is again produced, abſolutely ſimilar to that which before was analyzed. Cinnabar will again furniſh us with an example. When by chemical methods, the two ſubſtances which enter into the compoſition of this body, namely, mercury and ſulphur, are ſeparated, they are found to be in a ſtate of purity, ſimilar to that they poſſeſſed before, when united in the form of cinnabar; for, by uniting them, a body is again formed, in no reſpect differing from the cinnabar originally made uſe of. Unfortunately for the progreſs of ſcience, this kind of analyſis is very rare. Chemiſts are not ſo happy as to be able to apply it to many of the bodies they make experiments with; for except the neutral ſalts, and ſome other mineral bodies, there are no other ſubſtances in nature that admit of its application.

The falſe, or complicated analyſis, is that, by means of which, no other principles are ſeparated from a body, but ſuch as in their original ſtate poſſeſſed ſome other form, and conſequently cannot, by their re-union, compoſe again the body from which they were obtained. This kind of decompoſition takes place in moſt of the bodies analyſed by chemiſts; no other condition being requiſite, but that more than two principles enter into the combination to be examined, and that they have an affinity for each other. Many minerals, and all vegetable and animal matters without exception, are capable of no other kind of analyſis. Thus it is that ſugar, ſubmitted to diſtillation in a retort, affords an acid, an oil, and a coaly reſidue, which might in vain be employed in attempts to re-produce ſugar by combination. This kind of analyſis does not ſhow the ſtate in which the principles were before their ſeparation, and cannot, therefore, afford any conſiderable information; but, on the contrary, deſerves to be attended to with the greateſt caution. From reſults of this kind, have ariſen all the cenſure chemiſtry is loaded with. It has been urged, that bodies were deprived of their organization, and abſolutely deſtroyed in attempts to arrive at their principles. Neither can it be denied, but that this cenſure has been for a long time deſerved; but at preſent, the ſcience of chemiſtry, having become more circumſpect and enlightened, refuſes its aſſent to the deceitful analyſis to which it formerly had recourſe, and poſſeſſes the means of inquiring into the properties and component principles of bodies, without deſtroying or altering their nature. It proceeds ſtill farther; it appreciates, as we ſhall ſhow in the examination of vegetable ſubſtances, the re-action of the principles upon each other, and determines the cauſes which thus modify, change, and alter thoſe principles.

Syntheſis, or combination, which conſtitutes the ſecond method of proſecuting chemical inquiries, is the formation of a compound by the artificial re-union of ſeveral principles. Its utility, extent, and the dependence that may be placed on the reſults it affords, renders it by much the moſt valuable method. We may even affirm, that there is not a ſingle operation in chemiſtry, in which ſome combination does not take place. Chemiſts do not ſeem to have ſufficiently attended to this important circumſtance. In fact, the ſynthetical operations, or events, are not only more frequent, but more uſeful, than the analytical; and it would afford no very inadequate idea of chemiſtry, if we were rather to term it the ſcience of combination, than of analyſis.

Though theſe two methods are ſometimes employed ſeparately, it is nevertheleſs much more uſual to find them united. It often happens that a true analyſis cannot be made, but by the help of ſome combination. Falſe analyſes, or decompoſitions, are always attended with ſynthetical proceſſes, or new combinations. In a word, it is not unuſual to find, that a kind of analyſis follows as a conſequence from certain acts of combination; an event, which has not been known till very lately. The diſcovery of a great number of aeriform fluids, whoſe exiſtence was not formerly ſo much as ſuſpected, has ſhown, that in many operations which were ſuppoſed to be ſimple combinations, an elaſtic inviſible fluid is diſengaged with effervеſcence, and either eſcapes into the atmoſphere, or is received in veſſels, in which the ingenuity of modern philoſophers has taught us how to confine it. The greater number of combinations of two ſubſtances, hitherto thought to be ſimple, exhibit this kind of analyſis; and frequent examples will offer themſelves when we come to treat of neutral ſalts.

From this curſory account of the analyſis and ſyntheſis of the chemiſts, it is eaſy to be ſeen, that the whole art of chemiſtry conſiſts in promoting the mutual actions of bodies on each other, and carefully obſerving the phenomena that take place. It muſt not be forgotten, that theſe two methods are continually practiſed in the grand operations of nature, of which the chemiſt is only an imitator. The operations all depend on laws eſtabliſhed between bodies, and require nothing more, in order to their being perfectly accompliſhed, than that the bodies to be examined be put into a ſituation proper to act on each other. Theſe important truths require to be maturely weighed and conſidered with the moſt ſerious attention, by the ſtudent who is deſirous of penetrating into the depths of chemiſtry: And theſe, together with other truths explained in this firſt part, form the baſis of the ſcience.

Hence it is very eaſy to form an idea of the end or intention of chemiſtry, which is erroneouſly ſaid to conſiſt in the diſcovery of the principles of bodies. For it is clearly ſhown, that there are many bodies that cannot be ſeparated into principles, but are ſimple ſubſtances, as far as our preſent knowledge extends; yet theſe, though not ſuſceptible of analyſis, muſt have chemical properties, or powers of acting on other bodies, and of forming combinations with them. The true purpoſe or intention of chemiſtry therefore, is to inquire into the action of natural bodies on each other; to diſcover the order of their combinations; to eſtimate the force with which they tend to combine, and to remain in a ſtate of combination.

§ 2. *Concerning the uſeful purpoſes to which Chemiſtry is applicable.*

To give a view of the numerous advantages mankind derive from this ſcience, would require a ſeparate treatiſe; and as the nature of this work does not admit of our purſuing that ſubject at large, we ſhall content ourſelves with exhibiting the principal outlines, and dwelling more particularly on ſuch ſubjects, as in our opinion have not been ſeen in a proper point of view.

The great number of arts that are indebted to chemiſtry, may be ranged under two principal diviſions. The firſt comprehends all the mechanical arts, which are reducible to geometrical principles. The ſecond contains all thoſe arts, whoſe manipulations depend on chemiſtry, and may be properly termed chemical arts. This laſt claſs is much more numerous than the other. As they are all founded on chemical phenomena, it is eaſy to imagine that the rules of chemiſtry ought to direct the practice, and that this ſcience may ſimplify the proceſſes by new diſcoveries, render their ſucceſs more certain, and even extend their limits. Among theſe are, 1. The arts of making bricks, tiles, and the varieties of pottery; all which conſiſt in the preparation of different kinds of clay, and bringing them, by baking, to the requiſite degree of hardneſs. 2. The art of glaſs-making, which, by uniting a vitrifiable earth with a ſaline ſubſtance, produces a new ſubſtance, poſſeſſing great hardneſs, tranſparency, and durability, on expoſure to the air; a wonderful art, which, in its various applications, has been of the moſt eſſential ſervice to mankind. 3. The arts of extracting metals from their ores, of caſting, of purifying, or of alloying them with each other, owe their origin and progreſs to chemiſtry, and daily receive new advantages from the ſame ſource. 4. The vegetable kingdom affords materials to a great number of arts, which, like the foregoing, are under the dominion of chemiſtry: The arts of converting ſaccharine juices, or farinaceous bodies, into vinous liquors; of extracting from thoſe liquors the ardent ſpirit they contain; of ſeparating the ſpirit from the water, with which it is diluted in its firſt ſtate; of uniting this ſpirit to the aromatic parts of plants: The art of extracting the colouring matter of plants, and applying it to different ſtuffs: Of changing wine into vinegar, and uniting this laſt with various ſubſtances; of ſeparating from grain and other parts of vegetables, the precious matter deſtined to form bread; a digeſtible and light ſubſtance prepared from a dry and inſipid farinaceous powder; all theſe arts, and a very great number of others that cannot be enumerated in this place, are entirely chemical, and are indebted to that ſcience for their preſent perfection, and, in many inſtances, for their firſt invention.

This valuable ſcience has claims equally extenſive and important on the arts that convert the parts of animals to our uſe and advantage. Among theſe is the uſeful, though too little conſidered, art of cookery, whoſe true purpoſe is leſs to flatter the organs of taſte by capricious variations of form and flavour, than to render aliments of eaſy digeſtion by developing their taſte by boiling, or by mild and natural ſeaſoning. The arts of dreſſing, tanning, and currying ſkins, and of making hats, are of the ſame claſs; but one of the moſt important arts which occupies the middle rank between the arts, properly ſo called, and the ſciences, and to which it is particularly uſeful, is pharmacy. Every perſon concerned in pharmacy, has need of a very extended knowledge of chemiſtry, in order to know the alterations the matters he uſes are ſubject to, that he may prevent and correct them; to diſcover the changes compound medicines undergo; and, in a word, to determine inſtantly the combinations and decompoſitions that may follow from the mixture of ſimple drugs in extemporaneous preſcriptions. Every impartial perſon who reflects on this ſubject, will determine, that ſuch as are neceſſarily employed in pharmacy, ſhould, after acquiring the previous knowledge of natural hiſtory, indiſpenſable in becoming acquainted with the Materia Medica, pay the moſt ſerious and unremitted attention to chemiſtry. By theſe means, and by theſe alone, it is, that the art of medicine can be reduced to principles, and rendered equal to the performance of thoſe ſervices, which have long ſince placed it in the honourable eſtimation of ſociety.

A very tranſient proſpect of the ſciences, will ſufficiently ſhow the great benefits which they may derive from chemiſtry. Natural hiſtory is among thoſe that receive the higheſt advantages from it. The characters employed by the early naturaliſts to diſtinguiſh minerals, were taken only from their phyſical properties, as colour, form, conſiſtence, &c.; but theſe properties being ſubject to great variation, the bodies mentioned or deſcribed by the ancient philoſophers are no longer known, and the immenſe labours of the firſt naturaliſts are almoſt entirely loſt. The moderns have perceived, that in order to avoid this inconvenience, ſo deſtructive to the progreſs of natural hiſtory, it was neceſſary to follow another method. The method of chemical analyſis appeared to deſerve the preference; and the buſineſs is already in ſuch forwardneſs, that claſſes are eſtabliſhed among minerals, founded on the nature and quantity of the principles which enter into their compoſition. It is to the labours of Meſſrs. Bergman, Bayen, Monnet, &c. that we are indebted for the advancement of this part of natural hiſtory. Wallerius, Cronſtedt, and ſeveral other learned men, began the taſk of claſſing mineralogy upon chemical principles. M. Bucquet, in his latter courſes of lectures, improved on the knowledge theſe two celebrated naturaliſts have tranſmitted to us, by adopting a method of claſſing minerals on principles entirely chemical. M. Sage, who has analyzed a great number of minerals, has followed a method purely chemical in his diſpoſition of theſe bodies; and, though his theory has not yet been adopted by any chemiſt, it is certain that mineralogy is under great obligations to him; and that he ranks among thoſe who have cultivated it with the greateſt ſucceſs in France. M. Daubenton has availed himſelf of the labours of all his cotemporaries, and has adopted their methods and concluſions with that caution, which is the true character of a philoſopher, whoſe only aim is to diſcover and obtain the truth, ſeparated from the numerous uncertainties and errors, with which, unhappily for mankind, it is too often attended. Nothing, therefore, can be ſhown more evidently than the advantanges reſulting from the application of chemiſtry to natural hiſtory, as it is the only means of removing that obſcurity that muſt attend ſimple deſcriptions of external appearances. The juſt and truly valuable obſervation of M. Daubenton, deſerves to be conſtantly attended to by all chemical philoſophers. He warns them to be very careful in deſcribing the ſpecimens on which they make their experiments, in order that they may be underſtood by all naturaliſts, and to avoid that confuſion, which, according to that celebrated profeſſor, prevails throughout the works of many modern chemiſts. We have found no other means of avoiding this error, than that of uniting both ſciences in our lectures, and aſſociating the knowledge obtained from the works of naturaliſts, with that which chemical experiments daily produce.

It is not ſo clearly determined in the opinion of the world in general, that chemiſtry is uſeful in medicine. The errors of the chemical phyſicians of the laſt century, and the indifference many practitioners of the preſent time ſeem to have for this ſcience, have produced a diſadvantageous opinion in the minds of many perſons, which time alone can remove. In the mean time, however, it would be more prudent, inſtead of entertaining an ill-founded prejudice, to inquire with impartiality into the cauſe of the errors committed by chemiſts, into the means of preventing them, and of reſtoring to chemiſtry that eſtimation it has unjuſtly been deprived of. If the enthuſiaſm of the firſt phyſicians, who cultivated chemiſtry, miſled them, it does not follow that any concluſion can be drawn from thence that may be applied to the preſent time. The exactneſs which the moderns have introduced into every part of experimental philoſophy, ought to remove the apprehenſions of ſuch, as for want of acquaintance with the ſubject, are apt to imagine that chemiſtry is ſtill the dark, myſterious ſcience it was a century ago. By a due attention to the extent of its powers, and a careful uſe of them, there cannot be a doubt but it will be found of the higheſt utility to medicine. After this acknowledgment of the wanderings of the early chemiſts, let us finiſh the juſtification of the ſcience, by inquiring what departments of medicine are capable of deriving the greateſt advantages from its aſſiſtance. The two great branches of this vaſt ſcience, are theory and practice; which ought not to be ſeparated from each other, as ſome authors have thought fit to do. The ſtudy of medicine ought neceſſarily to commence with the anatomical hiſtory of man, and of animals. Anatomy can only be employed on the ſolids. But phyſiologiſts muſt be well aware, that the greateſt part of animal bodies is formed of fluids; by the motion of which, life is maintained. If, therefore, the attention were confined to the veſſels, without attempting to arrive at the nature and properties of theſe fluids, we ſhould be acquainted only with a part of the living economy. It belongs to chemiſtry to examine them; and it is chemiſtry alone, that can throw any light on their compoſition, and the changes they undergo, by the proceſſes there carried on during life. We cannot avoid having recourſe to this ſcience, in our endeavours to diſcover the true mechaniſm of the animal functions; the properties of the fluids ſeparated by the different viſcera; or the alterations ſuch fluids undergo during their time of remaining in the reſervoirs into which they are ſecreted, to underſtand the changes produced in them by motion, by heat, and by their admixture with other fluids, &c. A knowledge of the compoſition of animal fluids being once acquired, it will be neceſſary to enlarge and multiply our reſearches on ſubjects of different age, ſex, and temperament, in various climates and ſeaſons; and to purſue them among the different claſſes of animals; that by eſtabliſhing uſeful points of compariſon, the limits of ſcience may be extended.

The labour of the medical inquirer, is not confined to the ſtudy and examination of the properties of animal fluids in a ſtate of health; but requires to be carried farther. The kinds of alterations they are ſubject to, in the ſeveral diſorders that afflict the human frame, muſt be inquired into. A diſcovery what part of the animal liquids predominate in inflammatory, putrid, ſcorbutic, or ſcrophulous diſorders; or the analytical knowledge of the ſaline ſubſtances developed, and the nature of the extravaſated matter, with numberleſs other objects of reſearch, cannot but be of the utmoſt value and importance in the ſcience of medicine. We think it equally neceſſary to examine the ſolids, by chemical methods, as well in the ſound as in the diſeaſed ſtate; and, by a compariſon of their properties, endeavour to diſcover to which of the fluids they owe their formation; and this being known, we may proceed to conjecture, in morbific diſpoſitions, the ſolid or fluid that has ſuffered a change. This poſition, which we ſlightly mention in this place, will be more largely explained in the chapters relating to animal matters.

If it be thus eſtabliſhed, that the theory of medicine is capable of receiving the moſt eſſential advantages from chemiſtry, it is equally certain that the practice is no leſs in need of the ſame aſſiſtance; ſince both muſt of neceſſity accompany each other, and are promoted by the ſame means. And, in fact, it is eaſy to ſhow the immediate dependence of the practice upon the ſcience we are juſtly commending, without having recourſe to the ſecondary advantage the practical part of medicine cannot but receive from every real improvement of the theory. To begin with the art of preſerving health: Nothing can be more evident than that the choice of aliments and of air, cannot be made with any certainty, but in conſequence of chemical reſearches into the nature of foods, and the properties of the atmoſpheric fluid. Chemiſts alone can inform us of the quantity of nutritive matter contained in the aliments we make uſe of; the ſtate it is found in; the nature and quantity of the ſubſtances it may be combined with; the means of extracting, purifying, and preparing it, ſuitably to different ſtomachs; or of giving it the due degree of attenuation appropriated to every conſtitution of the internal parts. It is to this ſcience that we muſt apply for information, reſpecting the nature of the fluids that ſerve us for drink; the properties which water ought to poſſeſs for the purpoſes of life, and the means of examining into its purity, or diſcovering thoſe ſubſtances that vitiate it, but particularly the method of rendering it ſalubrious, ſo that it may be drank with ſafety; the principles and properties of fermented liquors; and the methods of examining into their compoſition, as well as to determine their ſalubrity, as the adulterations which they may have undergone. In a word, it is chemiſtry which ſhows the properties of the air which we reſpire, and without which, life could not for a moment be ſupported. The changes this ſubtle fluid is liable to, from various agents, and the nature of thoſe agents, the truly precious means of correcting its bad qualities, and rendering it fitter for the grand purpoſe of reſpiration, are among the diſcoveries of modern chemiſts. The efficacy of theſe means is eſtabliſhed on the ſureſt grounds, as ſhall afterwards be ſhown in the hiſtory of air.

The phyſician ought not to make uſe of medicines, unleſs he is acquainted with their nature; and in the inquiry, he muſt have recourſe to chemiſtry. This truth has been always ſo well eſtabliſhed, that writers on the Materia Medica have claſſed the medicaments according to their chemical principles. The obſervation of all ages has ſhown, that there is an intimate connection between the taſte of drugs, and the manner of their acting on the human frame; ſo that a good judgment may be formed of the medical properties of a ſubſtance from its taſte. Thus it is that bitters are ſtomachic, inſipid ſubſtances are mild and relaxing, ſweet and ſaccharine ſubſtances nutritive, and acrid matters are active, penetrating, and inciſive. Now, as the taſte is truly a chemical property, depending entirely on the tendency of bodies to combination, as we ſhall elſewhere ſhow, chemiſtry muſt of courſe be of great ſervice in the adminiſtration of medicines. It muſt not, however, be concluded according to the chemiſts of the laſt century, that the ſtomach reſembles a veſſel, in which operations are performed as in a chemical laboratory. The inteſtines are endued with ſenſibility, and a peculiar motion, that modify the nature and effects of remedies; and the diſcretion of an enlightened obſerver, ought always to regulate his imagination, ſo as to prevent his falling into any ridiculous hypotheſis. It cannot be denied, but there are caſes wherein medicines act in the firſt paſſages by means of their chemical properties; and in theſe caſes the phyſician may reaſon and conduct himſelf according to immediate deductions from chemical principles. Thus it is proved, by long experience, that in the diſeaſes of infants, the ſtomach and inteſtines are coated with a tenacious viſcous matter, of a manifeſtly acid nature. The abſorbent earths, and even the alkalis adminiſtered on ſuch occaſions, deſtroy this acid by combining with it, and form a neutral purgative ſalt that evacuates this noxious matter, by ſtimulating the inteſtines. Every diſorder which is attended with an accumulation of obſtructing matter in the firſt paſſages, neceſſarily demands a knowledge of chemiſtry in the exhibition of medicines, ſince it is certain that ſome ſubſtances act more powerfully on this matter than others, as acids for inſtance on putrid ſaburræ, and neutral ſalts on thick and glairy ſubſtances. But the greateſt advantage the practitioner can derive from this knowledge, is, without doubt, in thoſe unhappy caſes, wherein by miſtake or deſign, corroſive ſubſtances have been taken that might prove mortal by attacking the viſcera, and deſtroying their organization. Chemiſtry then lends its ready and ineſtimable aid to medicine, by affording ſubſtances capable of changing the nature of the poiſon by decompoſition; or of otherwiſe immediately ſtopping its pernicious effects. The work of M. Navier, a celebrated medical chemiſt of Chalons, points out the moſt efficacious means of preventing the deſtructive conſequences of the poiſons of arſenic, corroſive ſublimate, verdegriſe, and the preparations of lead; and notwithſtanding the declamations of certain phyſicians, who ſeem deſirous of excluding the ſciences from the practice of medicine, his work will receive the tribute of gratitude from poſterity.

Chemiſtry is not adequate to the counteracting the effects of all poiſons, but there is good reaſon to hope, that reſearches into the nature of vegetable and animal poiſons, if made with ſkill and care, would be attended with the diſcovery of remedies of ſufficient power to counteract them. Opium, and all narcotic vegetables, the acrid and cauſtic juices, ſuch as thoſe of ſpurge and euphorbium, the poiſonous plants, and more eſpecially the fungi, demand the particular attention of chemiſts, for the diſcovery of ſubſtances proper to obviate their dangerous effects. With no leſs utility, an inquiry might be made into the animal poiſons. We are already acquainted with the acid of ants, from the experiments of Margraaf and Fontana. Thouvenel has diſcovered ſeveral acrid matters in cantharides. Mead has made reſearches on the poiſon of the viper. Fontana has purſued the ſame ſubject, and has diſcovered that the lapis cauſticus immediately introduced into the wound made by this reptile, decompoſes or alters the poiſon, and prevents its deadly effects.

If it be poſſible, after what has been ſaid, to ſuppoſe that chemiſtry is not equal to the performance of the deſirable effects here pointed out, yet no one can deny that the ſcience of medicine is indebted to it for many uſeful remedies. It can never be forgotten that ſtibiated tartar, that heroic remedy, the uſe of which is at preſent ſo univerſal in France, with all the mercurial, antimonial, and martial preparations which are poſſeſſed of ſuch power and efficacy, are the products of chemiſtry; and that the gratitude and encouragement of medical profeſſors, as well as the public in general, is due to ſuch as devote themſelves to its improvement. For my own part, led by taſte as well as ſituation, to cultivate both theſe ſciences, it ſhall be my object to contribute with zeal to their advancement. I ſhall diſregard entirely the declamations of thoſe, who being but imperfectly acquainted with chemiſtry, have laboured to prove its uſeleſſneſs to medicine. I have devoted myſelf to the ſtudy of animal chemiſtry, and ſhall follow with ardour the labours already ſo well begun by the learned chemiſts who have preceded me in this uſeful career.

To conclude our obſervations on the utility of chemiſtry to medicine, we ſhall only add, that a knowledge of the former is neceſſary, in order to draw up a preſcription for any compound medicine to be made up by the apothecary. It happens daily, that perſons unacquainted with chemiſtry, commit the groſſeſt errors in their extemporaneous formulæ, by mixing together ſubſtances that either become changed by mutual decompoſition, or elſe refuſe to unite at all. In the caſe of decompoſition, the medicine cannot produce the effect, which the phyſician from his acquaintance with the component matter, was led to expect. Such errors, ſo prejudicial to the health of the patient, are no otherwiſe to be avoided, but by a knowledge of chemiſtry. It teaches to unite together ſubſtances capable of combining without decompoſition; it regulates and determines the proceſſes neceſſary for the preparation of compound medicines into which ſubſtances of different natures are made to enter; in a word it is the only guide in all pharmaceutic preparations. Without this guide, the phyſician is not only liable to the occaſional faults we have pointed out, but to numberleſs others, which though of leſs eſſential conſequence, muſt expoſe his ignorance to the apothecary; who, in the practice of his own art, cannot but be acquainted with a conſiderable number of chemical facts.

The uſefulneſs of chemiſtry in the arts, and the reſemblance between its proceſſes and the manipulations of artiſts, have often cauſed it to be confounded either with alchemy or pharmacy, by perſons ignorant enough to unite objects in their own nature ſo remote from each other. In the opinion of ſuch, the chemiſt is an artiſt inceſſantly employed in the vain ſearch of the philoſopher's ſtone. But thoſe who have acquired the leaſt knowledge of true chemiſtry and its purpoſes, will readily perceive the immenſe diſtance between the ridiculous and abſurd pretenſions of the alchemiſt, and the enlightened chemiſt; and more eſpecially the difference between the regular proceedings of the latter, compared with the inconſiſtent and uſeleſs proceſſes of the former. The error of the many, who regard chemiſtry as the art of preparing drugs, is much more pardonable; becauſe it does not confound chemiſts with the ignorant, and, at beſt, the uſeleſs operators of what is called the Grand Work, who, as Macquer ingeniouſly obſerves, are the workmen of an art that has no exiſtence; but aſſociates them with a reſpectable claſs of artiſts, whoſe labours are neceſſary to ſociety. But pharmacy being nothing more than a part of chemiſtry, or one of the many arts that are dependent on, or benefited by, its principles, the perſon who regards chemiſtry as the art of preparing remedies, will have but a very limited idea of this experimental ſcience: a ſcience of ſuch ſublimity and vaſt extent, that it not only contains within itſelf the much greater part of the numerous arts that diſtinguiſh civilized nations from ſavages, but extends its reſearches univerſally to the mutual actions of the component parts of bodies on each other; to the great improvement of natural philoſophy, which in many of its moſt important parts is purely chemical.

CHAPTER II.

THE HISTORY OF CHEMISTRY.

HE who devotes himſelf to the ſtudy of any ſcience, ought not to be ignorant of the outlines of its hiſtory. For ſuch a hiſtory, being a relation of ſcientific facts, fixes the dates of diſcoveries, points out the errors of our predeceſſors, and indicates the path that leads to ſucceſs. But as it might not tend to promote the immediate purpoſe of this treatiſe, if we were to do dwell on ſubjects that are in ſome meaſure foreign to it, we ſhall exhibit nothing more than the outlines of this hiſtory; without entering minutely into particulars, which may be found at length in many well written books. In particular, the treatiſe of Olaus Borrichius de ortu et progreſſu Chemiæ, the article Chimie in the Dictionnaire Encyclopedique, the diſcourſe at the head of Senac's Chemiſtry, l'Hiſtoire de la Philoſophie Hermetique, by the Abbe Lenglet du Freſnoy, the firſt chapter of Boerhaave's Chemiſtry, the Preliminary Diſcourſe to Macquer's Dictionary, &c. may be conſulted for this purpoſe.

For the purpoſe of exhibiting in a conciſe and methodical manner, the progreſs of the human mind in the ſtudy of chemiſtry, and the ſeveral advances made therein from time to time, we ſhall divide our hiſtory into ſix principal epochas.

EPOCHA FIRST.

The origin of Chemiſtry among the Egyptians, and its progreſs among the Greeks.

The origin of chemiſtry is not leſs obſcure than that of the other ſciences and arts in general. The patriarch Tubal Cain, who lived before the deluge, is ſaid to be the firſt chemiſt; but his knowledge is not affirmed to have extended beyond the working of metals. This man ſeems to have been the ſame, who is ſpoken of in fabulous hiſtory under the name of Vulcan.

It is among the Egyptians that we ought to place the true origin of this ſcience. The firſt of this nation, of whom mention is made as a chemiſt, is, according to Lenglet du Freſnoy, Thoth or Athotis, ſurnamed Hermes or Mercury. He was the ſon of Mezraim, or Oſiris, and grandſon of Cham. He became king of Thebes.

The ſecond king of Egypt, who was likewiſe a philoſopher, was named Sephoas. He lived 800 years after Athotis, and 1900 before Jeſus Chriſt. The Greeks have given him the ſurname of Hermes, or Hermes Triſmegiſtus. He is the ſecond Mercury, and is eſteemed as the inventor of natural philoſophy. Several hiſtorians have tranſmitted to us the titles of his works on philoſophy, which conſiſted of forty-two books. It does not appear that any of them treated of chemiſtry, though the ſcience has been called after him, the Hermetic Philoſophy.

Our information reſpecting the cultivation of chemiſtry in Eygpt, is very uncertain. It ſeems, however, that this ſcience made great progreſs in that country, ſince the Egyptians were in poſſeſſion of a great number of chemical arts; and in particular, that of imitating precious ſtones; of caſting and working metals; of painting on glaſs, &c.; but the chemiſtry, as well as the other arts and ſciences of this ancient people, are loſt. Their prieſts concealed them from the vulgar as myſteries, and only recorded them under the veil of hieroglyphics. The alchemiſts have perſuaded themſelves that ſome traces of their pretended art is to be found among theſe; and that the temple, which the Egyptians conſecrated to Vulcan, was in honour of alchemy.

The Iſraelites learned chemiſtry from the Egyptians. Moſes is placed in the number of chemiſts, becauſe of the knowledge by which he was enabled to diſſolve the idol of gold that people adored. It has been thought, and Stahl has written a diſſertation to prove it, that this ſolution of gold in water was performed by the help of liver of ſulphur; a proceſs which ſuppoſes a knowledge of chemiſtry of conſiderable extent.

Democritus of Abdera, who lived about 500 years before Chriſt, travelled into Egypt, Chaldea, Perſia, &c.; and it is affirmed, that he became acquainted with chemiſts in the firſt of theſe countries. Though the ſon of a man ſufficiently rich to receive and entertain Xerxes and all his attendants, he returned very poor to his own country, where he was received by his brother Damaſſus. In his retirement in a garden, near the walls of Abdera, he employed himſelf in reſearches into the nature of plants and precious ſtones. Cicero affirms, that in order that he might not be diſturbed from his ſpeculations by external objects, he deſtroyed his ſight, by keeping his eyes for a time fixed on the bright reflection of the ſolar rays, from a veſſel of poliſhed copper; a fact which, however, is denied by Plutarch. Pliny had ſo great a degree of eſteem and veneration for the knowledge of Democritus, that he even thought it miraculous.

There are ſome authors who reckon Cleopatra among the chemiſts, becauſe ſhe knew how to diſſolve pearls. They affirm, that the art of chemiſtry, well known to all the Egyptian prieſts, was conſtantly practiſed by that people, till the time of Diocleſian, who, according to Suidas, thought fit to cauſe their books to be burned, that he might ſubdue them with more facility.

EPOCHA SECOND.

The Chemiſtry of the Arabians.

After a long ſeries of ages, during which it is not poſſible to follow the progreſs of chemiſtry through the revolutions of empires, we find ſome traces of this ſcience among the Arabians, who cultivated it with ſucceſs.

During the dynaſty of the Achemides or Abaſſides, the ſciences, which had been long abandoned, were reſtored to their vigour.

Almanzor, the ſecond Califf, devoted himſelf to aſtronomy. Harum Raſchid, the fifth Califf, and cotemporary with Charlemagne, cauſed ſeveral books relating to chemiſtry to be tranſlated from the Greek.

In the ninth century, Geber of Thus, in Chorazan, a province of Perſia, wrote three works on chemiſtry, in which we find ſome tolerably good things. His beſt treatiſe is intituled, Summa perfectionis Magiſterii. He has written with conſiderable perſpicuity on diſtillation, calcination, and the reduction and ſolution of metals.

In the tenth century, Rhaſes, a phyſician of the hoſpital at Bagdat, firſt applied chemiſtry to medicine. Some of his pharmaceutic preſcriptions are ſtill in eſteem.

In the eleventh century, Avicen, a phyſician, likewiſe applied chemiſtry to medicine. His merit and knowledge raiſed him to the office of Grand Vizier; but the debauched life he led was the cauſe of his being degraded from that office.

EPOCHA THIRD.

The tranſition of Chemiſtry from the Eaſt to the Weſtern parts of the world during the Cruſades. The reign of Alchemy.

The art of making gold was in requeſt for a long time, according to the authors who have written concerning it; but the folly which gave birth to it was at its heighth during the interval between the eleventh and ſixteenth centuries. The chemical facts diſcovered by the Egyptians, collected by the Greeks, and applied to medicine by the Arabians, came to the knowledge of the four nations who travelled into the eaſt during the cruſades; namely, the Germans, Engliſh, French, and Italians; and each of theſe nations became immediately filled with ſearchers after the philoſopher's ſtone. As the immenſe labours to which they devoted themſelves have contributed greatly to the advancement of chemiſtry, it is neceſſary to be acquainted with ſuch of theſe extraordinary men as have moſt diſtinguiſhed themſelves.

During the thirteenth century, Albert the Great, a Dominican of Cologn, and afterwards of Ratiſbon, acquired the reputation of being a magician, and has left a work full of alchemical proceſſes.

Roger Bacon, born in 1214, near Ilcheſter, in the county of

Somerſet, ſtudied at Oxford. He repaired to Paris to ſtudy the mathematics and medicine. Many inventions are attributed to him; any one alone of which would have been ſufficient to have rendered his name immortal. Among theſe are the camera obſcura, the teleſcope, gun powder; he is affirmed to have made a ſelf-moving chariot, a ſpeaking head, a flying machine, &c. He was a cordelier, and was ſurnamed the Admirable Doctor. An accuſation of magic being preferred againſt him, cauſed his brethren to impriſon him. He retired to a houſe near Oxford, where it is ſaid he worked in alchemy. Borrichius ſaw the houſe, which was ſtill known by his name *.

Arnold of Villeneuve, born in Languedoc, in 1245, and died in 1310, ſtudied medicine at Paris during 30 years. He wrote a commentary on the Epiſtle of the Schola Salernitana. The alchemiſts eſteem him as one of their greateſt maſters. Borrichius in the year 1664, ſaw one of his deſcendants, an alchemiſt, in Languedoc.

The fourteenth century. Raymond Lullius was born at Majorca in 1235, came to Paris in 1281, where he became the diſciple of Arnold de Villeneuve. Robert Conſtantin affirms to have himſelf ſeen one of the Roſe Nobles that were ſtruck in the Tower of London, out of the gold made by him, during the reign of Edward the Fifth, in the years 1312 and 1313. He wrote ſome books on alchemy, in which are to be found ſome facts concerning the preparation of acids, or aqua fortis, and on the properties of metals.

The fifteenth century. Baſilius Valentinus, a Benedictine of Erfort in Germany, was well acquainted with medicine and natural hiſtory. He compoſed a book on antimony, to which he gave the pompous title of "Currus Triumphalis Antimonii," which was commented on by Kerkringius. In this book we find a great number of antimonial preparations that have ſince been offered to the world under different new names, and have been adminiſtred in the cure of diſorders with great ſucceſs.

Iſaacus Hollandus the father, and his ſon of the ſame name, have written books praiſed by Boerhaave, from which it appears, that they were acquainted with the properties of aqua fortis, and aqua regia.

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* This houſe, as I am informed, was ſtanding a few years ſince. T.

All theſe authors have in general written in the moſt obſcure and confuſed manner on the chemical art; and though they were acquainted with ſome proceſſes of diſſolution, extraction, purification, &c. their pretenſions were greatly beyond their knowledge, and ſcarcely any advantage can be derived from their labours.

EPOCHA FOURTH.

The univerſal Medicine; Pharmaceutic Chemiſtry; Alchemy oppoſed, from the ſixteenth to the middle af the ſeventeenth century.

The bad ſucceſs of the alchemiſts, and the ruin of their fortunes and reputation, were ſo far from diſcouraging chemical enterpriſes, that we find a prodigious number of perſons during the ſixteenth century, encouraged and ſupported by the enthuſiaſm of a Swiſs phyſician, named Paracelſus, who was born near Zurich, in 1493. This impetuous man pretended that there exiſted an univerſal remedy. He ſubſtituted chemical medicaments in the ſtead of thoſe of the Galenical pharmacy then in uſe, and cured many diſorders by mercurial preparations, which were then deemed ſcarcely curable, more eſpecially thoſe of the venereal kind. His miraculous cures ſeemed prodigious; but tranſported by ſucceſs far beyond the bounds within which he ought to have confined himſelf, he publicly burned the books of the Greek phyſicians. He died in the midſt of his triumphs in an inn at Saltzburgh, at the age of 48 years, after having promiſed himſelf immortality by the uſe of his ſecrets.

This folly, highly extravagant as it was, revived the ardour of the alchemiſts. Some among them, who vainly imagined they had ſucceeded in the diſcovery of the univerſal medicine, dignified themſelves by aſſuming the new title of adepts. Such were, at the commencement of the ſeventeenth century,—

1. The Roſicrucians, a kind of ſociety formed in Germany, of which nothing more was ever known in France but the title, and whoſe numbers continued unknown. Theſe pretended brothers affirmed, that they were in poſſeſſion of the ſecrets of tranſmutation, of the univerſal ſcience, and medicine; with the ſcience of occult things, &c.

2. A Coſmopolite, named Alexander Sethon, or Sidon, who performed the work of tranſmutation before a perſon of the name of Hauſſen. This laſt related the fact to Vander Linden,

the grandfather of the phyſician of that name, who collected a medical library.

3. Another named Thomas de Vagan, born in England in 1612. He travelled into America, where Starkey received gold from him. He correſponded with Boyle. This is the ſame adept, who in France gave his powder of projection to Helvetius. The latter, after this pretended miracle, which was nothing more than an artful trick, wrote a diſſertation "De vi-" tulo aureo, &c."

The ſucceſs that attended the adminiſtration of chemical medicines by Paracelſus, was productive however of ſome permanently good effects; for it induced ſeveral men of abilities to enter into the inquiry, and to write uſeful works on the preparation of chemical medicines. Such are the writings of Crollius, Schroder, Zwelfer, Glaſer, Tachenius, Lemery, &c. and the Pharmacopeiæ, publiſhed by ſeveral faculties of medicine.

Glauber, a German chemiſt, about this time rendered an eſſential ſervice to chemiſtry, in examining the reſidues of operations, which former operators had always thrown aſide as uſeleſs, and diſtinguiſhed by the names of caput mortuum, or terra damnata. By this means he diſcovered the ſalt named after him, and the vitriolic ammoniac; and threw great light on the chemical proceſſes for preparing mineral acids, &c.

Some of the promoters of chemical ſcience ſubſequent to Paracelſus, were not entirely cleared of the ideas his ungoverned imagination gave birth to. Such were Caſſius, known by his precipitate of gold; Sir Kenelm Digby, who believed in the ſympathetic action of medicaments. Libavius, whoſe name is affixed to a preparation of tin. Van Helmont, famous for his opinions in medicine, and the chemical notions he has propagated. And laſtly, Borrichius, a Daniſh phyſician and chemiſt, who firſt diſcovered and publiſhed the method of inflaming oils by the nitrous acid, and is entitled to the reſpect and gratitude of the world, for having bequeathed his library and chemical laboratory to the uſe of indigent ſtudents of medicine.

Alchemy, at that time, was in great danger from two celebrated men, who ſucceſsfully combated its tenets. The one was the famous Kircher, a Jeſuit, to whom we are indebted for a grand and ſublime work intituled, Mundus Subterraneus; the other was the learned phyſician Conringius.

EPOCHA FIFTH.

The origin and progreſs of Philoſophical Chemiſtry, from the middle of the ſeventeenth to the middle of the eighteenth century.

Chemiſtry had not hitherto been treated philoſophically. The chemical arts had been deſcribed, medical formulæ had been given, and the nature of metals had been laboriouſly inquired into with a view to the making of gold, or of the univerſal medicine (deluſive views which ſtill miſlead the ignorant and ethuſiaſtic); but nothing more had been done. The facts aſcertained were many, but no one had yet collected them, and, as the celebrated Macquer happily obſerves, there were many branches of chemiſtry in being, though the ſcience itſelf was not yet in exiſtence.

Towards the middle of the ſeventeenth century, James Barnet, phyſician to the king of Poland, arranged the principal known facts in a methodical manner, and added obſervations in his philoſophical chemiſtry. The book of this learned man is the more valuable on account of his being the firſt perſon who attempted to form a complete body of chemiſtry, and ranked it among the ſciences

Bohnius, Profeſſor at Leipſic, likewiſe compoſed a book of ſcientific chemiſtry, which had great ſucceſs, and was for a long time the only elementary book on this ſubject.

Joachim Beccher of Spires, a man of the moſt extenſive genius, phyſician to the electors of Mentz and Bavaria, went far beyond the two authors laſt ſpoken of, and cauſed even their names to be forgotten. In his ſublime work, intituled, "Phyſica Subterranea," he united all the known facts of chemiſtry, and deſcribed them with aſtoniſhing ſagacity. He has even pointed out by conjecture, a great part of the diſcoveries made to this day; ſuch as the aeriform ſubſtances; the poſſibility of reducing animal bones into a tranſparent glaſs, &c. This work was commented on by a celebrated phyſician, whoſe name fixes a moſt brilliant epocha of chemiſtry. J. Erneſt Stahl, born with a ſtrong paſſion for chemiſtry, undertook to comment and improve the doctrine of Beccher. His attention was more particularly directed to aſcertain the exiſtence of the inflammable earth, which he called phlogiſton. Equal to Beccher in genius, but ſuperior in accuracy of operation and order of reſearch, he compoſed a treatiſe on ſulphur, a work on ſalts, and another intituled Trecenta Experimenta, which have gained him immortal glory, and placed his name among the firſt of his age.

Boerhaave, in the midſt of numberleſs occupations, cultivated chemiſtry, and compoſed a celebrated and truly profound work on this ſcience. His treatiſes on the four elements, and eſpecially that on fire, are maſterpieces to which at that time it was ſcarcely poſſible to have made any addition. He was likewiſe the firſt who attempted the analyſis of vegetables, and diſcovered the ſpiritus rector, &c.

The theory of Stahl has been followed by the whole chemical world, and received a new acceſſion of ſtrength from the two celebrated brothers M. M. Rouelle, whoſe too early loſs is ſeverely felt by the ſcience, and to whom chemiſtry owes its origin in France.

The illuſtrious Macquer, who will be long lamented by every lover of ſcience, has contributed in a moſt eminent degree to the advancement of this ſcience by his moſt excellent works, which are with the greateſt juſtice eſteemed in every part of Europe, as the ſureſt guides to chemiſtry. Beſides the great obligations the world is under to him for his Elements and Chemical Dictionary, his own particular labours and diſcoveries on arſenic, Pruſſian blue, dying ſilk, on clays for pottery, &c. are ſufficient to immortalize his name, and entitle him to the gratitude of poſterity.

EPOCHA SIXTH.

Pneumatic Chemiſtry; the preſent time.

Stahl, entirely buſied in demonſtrating the exiſtence of phlogiſton, and following it through all its combinations, ſeems to have overlooked the influence of the air in the greateſt part of the phenomena in which he attributes ſo great an energy to the inflammable principle. Boyle and Hales had nevertheleſs already proved the great neceſſity of attending to this fluid, in the operations of chemiſtry. The former had obſerved the difference between the chemical events that happened in like circumſtances in the air and in vacuo. The latter had obtained from a great number of bodies a fluid which he ſuppoſed to be air, but in which however he had obſerved ſeveral peculiar properties, ſuch as odour, inflammability, &c. according to the various ſubſtances they proceeded from. He thought the air was the cementing principle, or cauſe of ſolidity in bodies.

Dr. Prieſtly, in repeating a great part of the experiments of Hales, has diſcovered many fluids, which though they reſemble air, differ from it in all their eſſential properties. And in particular, he obtained from metallic oxyds or calces, a kind of air, much purer than that of the atmoſphere.

M. Bayen, a chemiſt ſo juſtly celebrated for the exactneſs of his operations and experiments, examined the oxyds of mercury, and diſcovered that they were reducible without phlogiſton, and that during reduction they emitted an aeriform fluid in great abundance.

M. Lavoiſier proved very early, by a great number of valuable experiments, that a portion of the air becomes combined with ſuch bodies as are calcined or burned. In conſequence of this he eſtabliſhed a ſect or claſs of chemiſts, who began to doubt the preſence of phlogiſton, and attributed to the fixation of air, or its diſengagement, all the phenomena that Stahl ſuppoſed to depend on the ſeparation or combination of phlogiſton. It muſt be granted, that this doctrine has the advantage over that of Stahl in its proofs, being more ſtrict, and is ſo much the more ſeducing, as it agrees better with the accurate and rigorous manner of proceeding, which is at preſent adopted in the ſtudy and cultivation of natural philoſophy. This ſeemed to be the caſe in the opinion of the late M. Buquet, who, in his two or three laſt courſes, appeared to give it the preference. The wiſeſt and doubtleſs the only proper conduct to be purſued on this occaſion, is to wait till a great number of facts ſhall have completely demonſtrated, that all the phenomena of chemiſtry are explicable according to the pneumatic theory, without admitting phlogiſton. M. Macquer, though well aware of the great revolution theſe new diſcoveries could not but occaſion in chemiſtry, did not admit the opinion, that every fact is explicable without ſuppoſing the exiſtence of an inflammable principle; and inſtead of phlogiſton, whoſe exiſtence has never been fairly proved, he has ſubſtituted light, the action and influence of which in chemical appearances cannot be called in queſtion.

Since the death of that celebrated chemiſt, the ſcience has gained ſo much by the new diſcoveries, that the modern theory daily acquires new acceſſions of force: The large maſs of facts I have collected during the ſpace of twelve years attention to this ſcience, the number of experiments which I have repeated, have convinced me that it is abſolutely impoſſible to avoid admitting this theory; and that ſuch philoſophers as continue to ſupport, with more or leſs heat, the doctrine of phlogiſton, all give proofs in their works that they are not perfectly acquainted with the ſcience, or are in ſome reſpect deficient in the art of making experiments.

CHAPTER III.

CONCERNING THE CHEMICAL ATTRACTIONS.

In the foregoing chapter we have obſerved, that the means uſed in the performance of chemical operations, which are in general referable either to analyſis or ſyntheſis, are founded in nature; and that chemiſts are no more than imitators. This truth will be more ſtrongly eſtabliſhed by the explanation of the chemical affinities which we are about to give.

The leaſt progreſs in the ſtudy of natural philoſophy is ſufficient to impreſs the mind of the obſerver with a knowledge of that wonderful force eſtabliſhed between bodies, by which they mutually attract each other. All the phenomena in nature are dependent on this law, which the philoſopher contemplates with admiration, and the moſt uninformed inquirer cannot conſider without ſome degree of perplexity and aſtoniſhment.

The ſmalleſt bodies, as well as the immenſe maſſes that are compoſed by their union, are alike ſubject to this force, ſo neceſſary for the preſervation of the harmony of the univerſe: But its laws appear either to be eſſentially different, or differently modified, according to the maſs, bulk, or diſtance of the bodies acted on by its power. Without inquiring into its effects on the planetary* bodies, whoſe diſtances and motions it governs, let us obſerve what happens on the globe we inhabit, and endeavour to diſcover its laws of action.

Natural philoſophy teaches us, that two ſolid bodies of the ſame kind, when moiſtened and placed in contact, adhere together with ſo much the more force as the ſurfaces at which they touch are more poliſhed and extended. Thus two planes of glaſs, or two ſections of a metallic ſphere ſlipped upon each other, with preſſure, become united, and often require a very conſiderable effort to ſeparate them. This force gives birth to all the phenomena obſerved in chemiſtry; and it is therefore of the higheſt importance to ſtudy with care, all the laws and circumſtances that accompany it.

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* The celebrated Bergman (de Attractionibus Electivis) and others, as well as our author, from a wiſh to generalize, and in conſequence of a too ſuperficial view of the univerſal laws of attraction, have erroneouſly ſuppoſed that gravity, or the planetary attraction, might be ſo varied, when bodies became nearly contiguous, as to be modified or converted into the chemical affinity, or elective attraction obſerved between the minute parts of bodies. See Newtoni, Prin. I. § 13. T.

The greater number of chemiſts have denominated this force *affinity*, or *relation*, becauſe it has been thought that it depended on an analogy or conformity of principles in the bodies between which it exiſts. Bergman has called it *chemical attraction*, though its effects are very different from the planetary attraction obſerved by Newton; as, however, it appears to be only a modification of it, we ſhall adopt that term. This attraction may take place between bodies of the ſame, or of different natures. Let us obſerve it under theſe reſpective points of view.

§ 1. *Concerning the Attraction that takes place between Bodies of the ſame kind, or the Affinity of Aggregation.*

When two bodies of the ſame nature, as for example, two globules of mercury placed in the point of contact, tend, by virtue of this force, to unite, and the union is ſuffered to take place, a ſphere of greater magnitude, but of entirely the ſame nature, is formed. This force, therefore, produces no change, except in the phyſical, or obviouſly apparent qualities of bodies. It joins together parts of the ſame kind, which before were ſeparate; augments the bulk or magnitude, by confounding the maſſes, and forms one ſimple body out of ſeveral. It is named the affinity or the attraction of aggregation, to diſtinguiſh it from that between bodies of different natures. It produces an aggregate, in which, though the phyſical properties are changed, the chemical qualities are not ſenſibly altered. The aggregate is nothing more than a coherent body, whoſe molecules are united by the force of aggregation. It muſt be diſtinguiſhed from the maſs called a heap, which, though conſiſting of parts of the ſame nature, has not coherence throughout; as well as from a mixture which is taken to denote an incoherent maſs of diſſimilar particles. An example will illuſtrate this. Flowers of ſulphur, or ſulphur in powder, whoſe parts have no adheſion, but may be ſeparated by the ſmalleſt efforts, conſtitute a heap, on the parts of which, relatively conſidered, the affinity of aggregation does nót act. If this be mixed with another heap, as of nitre in powder, a mixture by confuſion will be had. But if, by the help of fuſion and cooling, the power of aggregation be cauſed to act, then the molecules, or integrant parts, brought towards each other during their liquefaction, unite and adhere together in ſuch a manner, as, that when cooled, they form a ſingle maſs or ſolid, which is a true aggregate.

The force or affinity of aggregation has different degrees, meaſurable by the effort or power neceſſary to be employed in ſeparating the integrant parts. We may diſtinguiſh four kinds of aggregates, under which all bodies in nature may be compriſed.

1. The hard or ſolid aggregate, in which the force that unites the integrant parts, is very conſiderable, and which cannot be deſtroyed, but by ſome very violent re-action. There are many degrees of aggregation under this claſs, from the hardneſs of the precious ſtones or rock cryſtal, to the ſoftneſs of the moſt yielding wood. Its character is to form a maſs, whoſe different parts cannot be ſenſibly moved amongſt each other, without breaking or ſeparation.

2. The ſoft aggregate is that whoſe parts, though coherent, may nevertheleſs be ſlided upon each other by a ſmall force, ſo as to change their reſpective ſituation. The force that unites the parts of a ſoft body, is leſs than in ſuch as are hard; and leſs re-action is neceſſary to deſtroy it.

3. The fluid aggregate. Its integrant parts are ſo ſlightly united together, that the ſmalleſt effort is not only ſufficient to cauſe them to ſlide, or change ſituation amongſt, but alſo to ſeparate them from each other.

4. Laſtly, The aeriform aggregate, whoſe integrant parts are too ſmall to be perceived, and in which the affinity of aggregation is the leaſt poſſible. The air of the atmoſphere furniſhes an example *.

Theſe four kinds of aggregate are no more, properly ſpeaking,

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* The aeriform aggregate is here erroneouſly defined or deſcribed. It is that whoſe denſity is not ſufficiently great, to afford obvious indications of its preſence, and in which the affinity of aggregation is negative, cauſing the integrant parts to repel each other. T.

than degrees of the ſame force, which it is nevertheleſs of great conſequence to diſtinguiſh with care, becauſe their ſtate and diverſity have a ſingular influence on chemical phenomena. This is proved in a very ſatisfactory manner, from the conſideration, that many bodies are capable of being ſucceſſively put into each of theſe four ſtates. Water, in the form of ice, is a ſolid aggregate. Its hardneſs is the greater in proportion as its temperature is lower; when expoſed to the temperature of 32° Fahrenheit, it aſſumes a kind of ſoftneſs, before it paſſes to a ſtate of fluidity. This laſt mentioned ſtate is well known in all climates; and philoſophers have computed its force of expanſion when in the ſtate of vapor, or in the aeriform aggregation. The ſame is the caſe with metals, fatty ſubſtances, concrete oils, wax, &c.

In proportion as we advance in the knowledge of the laws of chemical attraction, we ſhall perceive ſtill more the neceſſity of diſtinguiſhing and attending to theſe four kinds of aggregation. This is more particularly neceſſary, in comparing the force of aggregation with the ſecond kind of affinity next to be examined.

As theſe two forces, which ſeem to depend on the ſame cauſe or principle, are nevertheleſs always oppoſed to each other in chemical phenomena, ſo that it may even be inferred from the facts we ſhall exhibit, that they are in the inverſe ratio of each other *, it is neceſſary, when the chemiſt wiſhes to cauſe the one to act, that he ſhould diminiſh the other. Now, the attractive force we are ſpeaking of, is almoſt always that which he has occaſion to diminiſh, and it is likewiſe modifiable at pleaſure, by means in the power of the artiſt.

To deſtroy or diminiſh the affinity of aggregation, nothing more is required, than to oppoſe to the coheſion of the parts of the aggregate, an external force more than equal to that which retains them together, which conſequently muſt be greater or

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* This oppoſition of the affinities of aggregation and combination, muſt reſt entirely on the reaſoning of the author, in the following pages. To me it ſeems neither fairly deduced, nor probable in itſelf. A variety of important circumſtances, ſome of which are unknown, are included in this, and almoſt every other queſtion concerning the affinities. They cannot here be entered into; but the preſent may perhaps be decided, by anſwering the following. Are there not many operations in which an increaſe of temperature, at the ſame time weakens both the powers of aggregation and combination and the contrary? If this were not the caſe, could any ſeparation be made by mere heat, without an intermedium? And if heat be matter, and be the intermedium in ſuch caſes, the affinity of aggregation, as it is called, is out of the queſtion. T.

leſs, in proportion to that adheſion. This is the leading principle in the preparatory operations, whoſe ſole purpoſe * is to deſtroy the affinity of aggregation: Pulverization, grinding, filing, raſping, cutting, are operations that oppoſe the coherence of ſolids, and ſerve to ſeparate their parts. Heat and evaporation produce the ſame effect upon fluids, as well as upon moſt ſolids which are capable of becoming ſoft or melting. But theſe laſt methods, in which heat is the agent which divides bodies, depend themſelves upon a chemical attraction of the ſecond kind. The ſame may be ſaid of diſſolution in water.

As art is poſſeſſed of numberleſs means of oppoſing the force of aggregation, ſo likewiſe it affords others for reſtoring, and cauſing it to act again with all its energy. All its manipulations for this purpoſe, conſiſt in placing the bodies, whoſe aggregation it is propoſed to reſtore, in a ſtate of diviſion and fluidity, ſo that the particles of theſe bodies may be at liberty to obey the power of attraction, by applying to each other thoſe of their ſurfaces which are beſt adapted to unite, and to form an aggregate, the regular figure and coheſion of which often equal, and ſometimes even ſurpaſs thoſe of natural bodies of the ſame kind. On this occaſion we muſt remark, that all aggregate bodies may be divided into two claſſes; namely, regular or irregular. Nature has given to every body the property of preſenting itſelf under one or other of theſe two ſtates; art, ever emulous, and often the rival of nature, can at pleaſure produce either. All bodies capable of paſſing through the different ſtates of aggregation, before enumerated, and more eſpecially ſalts and metals, may, according to the management of the artiſt, in their paſſage from fluidity to ſolidity, appear in the ſhape of an irregular maſs, or in that of a body with regular facets, which is called a cryſtal. Nothing more is neceſſary to produce the former ſtate, than to keep the particles whilſt fluid, whether by heat or by water, very near each other, and to cauſe the liquefaction ſuddenly to ceaſe, ſo that coming into contact all at once, the attraction of aggrega-

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* The purpoſe is to increaſe the ſurfaces, that the mutual action of bodies on each other, being carried on at the ſame time, among a great number of parts, may be ſooner finiſhed, and the intended proceſs completed. The affinity of aggregation impedes combination in no other way, than by covering the internal parts. A lump of ſugar is ſlower in diſſolving, if put into water, than the ſame quantity in powder; becauſe, in the former caſe, the external parts muſt be diſſolved and removed, before the internal parts can be acted on. T.

tion may cauſe them to unite into a ſolid maſs. But, on the contrary, cryſtallization requires that the parts of the bodies in which it is to be produced, ſhould be kept ſufficiently diſtant from each other, that they may be, as it were, in equilibrium ſome time before they unite, and may mutually preſent to each other the ſurfaces that beſt agree with each other. After theſe details, it is clear that cryſtallization is entirely the conſequence of the affinity of aggregation. It is in this point of view that we have here conſidered it; and ſhall reſerve our future obſervations on the ſubject, to the other parts of this work.

§ 2. *Concerning the Chemical Attraction between two Bodies of different Natures, or the Affinity of Compoſition.*

When two bodies of different kinds have a tendency to unite, they then combine by virtue of a force different from that we have hitherto ſpoken of, and which is named the *affinity of compoſition*, or rather the *attraction of compoſition* [a]. This kind of attraction, more neceſſary to be underſtood than the former, takes place in all the operations of chemiſtry, none of which can be explained without it. This principle was known in the earlieſt times, but it was not attended to with ſufficient care, till experience had ſhown that its influence on the practice, is equal to that on the theory of the ſcience we are treating of. It is this doctrine that muſt guide the practitioner in the reſearches neceſſary for the advancement of chemiſtry, and muſt be conſulted by the philoſopher who collects and compares the facts. It is the compaſs by which both muſt ſteer; and it may be truly affirmed, that he who is intimately acquainted with the chemical attractions, knows every thing that the moſt ſublime chemiſtry has to offer.

Well convinced of this truth, we ſhall endeavour firſt to collect with fidelity all the facts that relate to them, and afterwards to explain the hypotheſes that have been invented, reſpecting their cauſe.

Obſervation, the parent of chemiſtry, as well as of every experimental ſcience, has ſhown that the attraction of compoſition preſents conſtant and invariable phenomena, which may be regarded as eſtabliſhed laws, obvious to all but thoſe who are unacquainted with the method of ſtudying nature. Theſe laws, founded on a great number of well eſtabliſhed facts, may be reduced to the eight following.

Firſt Law of the Attraction of Compoſition.

The attraction of compoſition does not take place, but between bodies of different natures.

This firſt law is invariable, and ſubject to no kind of exception. In order that two bodies may combine, and form a compound, it is a neceſſary condition that they ſhould be of different kinds. In fact, if two bodies of the ſame nature be united, the reſult will be nothing but an aggregate, whoſe maſs and magnitude only will be augmented without the loſs of any of its eſſential properties, and the union will be preſerved by the affinity of aggregation, as has been already ſhown. Thus two pieces of wax, reſin, or ſulphur, are united by heat. The difference between the affinities of aggregation and of compoſition, may hence be eaſily conceived.

This law is ſo true and ſo conſtant, that the affinity of combination is never ſo powerful, as when the bodies, between which it is exerted, are of the moſt different kinds. Thus it is that acids, whoſe properties are ſo oppoſite to thoſe of alkalis, combine and form the moſt perfect compounds with them. The ſame oppoſition of properties is obſerved between alkalis and ſulphur, alkalis and oils, acids and metals, ſpirit of wine and water, &c. all which have an exceeding ſtrong tendency to combine with each other, and to form the moſt perfect compounds, though their nature is totally different.

It is ſtill more neceſſary to attend to this leading principle, of the affinity of compoſition, becauſe many chemiſts, with Stahl at their head, have endeavoured to prove that bodies never entered into combination, but in conſequence of a certain agreement, or reſemblance of their properties; an opinion which muſt of courſe be rejected, when the full extent of this law is underſtood. On peruſing the writings of the greateſt chemiſts on this ſubject, it is ſeen that the reſemblances they endeavour to find between ſubſtances that have a great tendency to unite, are always very remote; and that, by following the ſame method, it is poſſible to find others equally ſtrong between the moſt diſſimilar bodies. It is, however, not difficult to obſerve, that theſe great philoſophers were deſirous of rendering the theory of chemical attractions more intelligible, by means of this explication; and thoſe who are aware of the extreme difficulty that attends the eſtabliſhment of theory, in any-branch of human knowledge, will be ready to conſider their efforts with the gratitude to which they are entitled. Their works are of the higheſt utility, by the illuſtrative arrangement and connection of the facts they have brought together. But our firſt homage is due to truth, which compels us to avow our ignorance of the cauſe of this extenſive ſimilarity of facts which we offer as a law of nature, rather than to have recourſe to an analogy, which is contradicted by examining into the properties of bodies.

Second Law of the Attraction of Compoſition.

The attraction of compoſition does not take place, except between the ultimate particles of bodies.

In order to conceive this law as it really exiſts, it is neceſſary to diſtinguiſh thoſe ſubjects concerning which the chemiſt reaſons, from others properly called phyſical. The latter are bodies whoſe exterior properties, ſuch as maſs, bulk, ſurface and figure, may be ſubmitted to computation, and appreciated by the ſenſes. The natural philoſopher or mechanic is buſied in the conſideration of aggregates. Chemical ſubjects, on the contrary, are bodies that have loſt their aggregation, and conſequently no longer exhibit the phyſical properties of aggregates to the ſenſes. They are particles ſo ſubtle, that their figure and volume cannot be known from meaſurement. Bodies do not obey the attraction of compoſition, till they have been reduced by the preparatory operations, to the requiſite degree of minuteneſs; and the chemiſt ſucceeds in combining them, only by preſenting them to one another in this ſtate of diviſion. It ſeems as if this property were confined in its operation to the infinitely ſmall particles, or ultimate molecules of bodies. Hence it appears, that the affinity of compoſition differs from the attraction ſubſiſting between large bodies. This difference is ſtill more ſtriking, when we conſider the oppoſition which is obſerved between the attraction of aggregation, and the attraction of compoſition. This oppoſition is ſo well eſtabliſhed, that I can venture to advance, as a chemical axiom, that the ſtronger the attraction of combination, the weaker the attraction of aggregation[b]. Theſe two forces ſeem to be oppoſed to, and mutually to counteract each other. In fact, the attraction of aggregation oppoſes the combination of bodies, and therefore ſuch as have a ſtrong force of aggregation, have very little tendency to enter into combination; while ſubſtances, that have little or no aggregation, have, at the ſame time, a very ſtrong diſpoſition to combine with others. Among the gaſes, for example, which of all known ſubſtances are thoſe whoſe aggregation is weakeſt, there are ſeveral whoſe tendency to combination is ſo ſtrong, that they unite with the greateſt vivacity to almoſt all natural bodies. Neverthelеſs, we ſhall hereafter ſee that this takes place only when the heat which is combined in elaſtic fluids, adheres but weakly to its baſe, and that the aeriform ſtate very frequently oppoſes combination, as is obſerved in pure air.

Third Law of the Attraction of Compoſition.

The attraction of compoſition can exert its action on more bodies than two.

This law of chemical attraction is one of thoſe we are leaſt acquainted with, and has been hitherto but very imperfectly inquired into. Many combinations of two bodies are known. Fewer of three, and ſtill fewer of four bodies, united by equal affinity, have been noticed. The metals alone preſent ſuch combinations, and may be combined with two, three, or four. It is probable that combinations of more than four, as for example, ſix or eight bodies may exiſt; but art has hitherto thrown very little light on this ſubject. The cauſe of the ſlow progreſs of the ſtudy of this law, will be ſhown, when we come to treat of the eighth law. The attraction that may take place between many bodies, is denoted by their number, by ſaying the attraction of two, three, four bodies, and ſo forth. The rapid advancement of modern chemiſtry, the multiplicity of reſearches that are purſued, and the ſcrupulous exactneſs of the preſent methods, give us reaſon to hope that theſe attractions, which are called *complicated*, will ſoon become better known[c].

Fourth Law of the Attraction of Compoſition.

In order that the attraction of compoſition may take place between two bodies, it is neceſſary that one of the two at leaſt ſhould be in a ſtate of fluidity.

This law has been long known to chemiſts, and is expreſſed by the following axiom, *Corpora non agunt niſi ſoluta.* The moſt connected and exact obſervations have ſhown that two ſolid ſubſtances cannot unite into combination with each other. Whence it happens, that bodies, which have the greateſt tendency to unite, cannot effect it, unleſs one of them be in the ſtate of fluid aggregation. The more fluid the bodies which the chemiſt is deſirous of combining, are, the leſs aggregative force they have, and conſequently the more eaſily and intimately they may be united. It is for this reaſon, that no combination is more rapidly or more perfectly made, than when two aeriform bodies are brought into contact, as the muriatic acid gas, and ammoniacal gas.

Though two ſolid bodies can never combine, yet there are certain circumſtances in which dry ſubſtances reduced to fine powder, act with ſufficient energy on each other, to unite and form a new compound. Thus I have obſerved, that the cauſtic fixed alkalis, unite, when cold, by ſimple trituration with ſulphur, antimony, and kermes mineral, as I ſhall elſewhere deſcribe; but in this caſe, the extreme diviſion of the two bodies, and the moiſture of the atmoſphere, attracted by the ſalt which ſoon deliquiates, are of ſingular advantage to the combination, and in fact bring it within the law we are treating of.

It is not always neceſſary that both the bodies we wiſh to combine, ſhould be fluid, but only that one of them ſhould be ſo. During their union, a phenomenon takes place, which chemiſts call diſſolution or ſolution. It is the attenuation, diviſion, and total diſappearance of the ſolid body placed in contact with the fluid. To underſtand the cauſe of this phenomenon, it is to be conſidered, that the attraction of combination which exiſts between two ſubſtances, the one fluid, and the other ſolid (as, for example, the ſulphuric acid and a piece of calcareous ſpar), is ſtronger than the aggregation that unites the particles of ſpar, and cauſes it to poſſeſs a ſolid form. Now, ſince by the third law this attraction cannot take place, but between ſmall bodies, it becomes a neceſſary condition that the ſpar muſt be reduced into very ſmall particles, by the loſs of its aggregation, before it can unite with the ſulphuric acid, and form ſulphate of lime. The ancient chemiſts, in all ſolutions, made a diſtinction between the ſolvent and the body intended to be diſſolved; the former being the fluid, and the latter the ſolid. This diſtinction, which ſuppoſes in the fluid a force ſuperior to that exiſting in the ſolid aggregate, cannot be admitted by modern chemiſts, who obſerve, with M. Gellert, that in ſolution the action is equal on both ſides, and that, in the example here cited, the ſulphuric acid would not deſtroy the aggregation of the ſpar, if this laſt did not tend to combine with the ſulphuric acid with an equal force. The term ſolvent, at preſent applied to fluids, is therefore far from being chemical, and preſents to the mind the idea of a mechanical action; for which reaſon it would be better to reject it altogether. But as cuſtom has unfortunately prevailed, it becomes neceſſary to remember, that when one body is ſaid to diſſolve another, nothing more is intended to be expreſſed, than the ſtate of fluidity of the former; and that no greater activity is attributed to it, than to the ſolid, which poſſeſſes exactly the ſame, or even a ſuperior degree of force; ſince the tendency it has to combine with the fluid, overcomes its aggregation, or deſtroys it entirely.

The falſe idea that has till lately prevailed concerning ſolution, has doubtleſs ariſen from the mechanical theory of this operation of nature, which certain philoſophical chemiſts have invented. This theory, which is found in every page of Lemery, conſiſts in ſuppoſing the ſolvent an acid, for example, to be an aſſemblage of very acute points, and the body to be diſſolved, as poſſeſſing an infinite number of pores, in which the points of the acid are received, which tear aſunder its parts, and by that means reduce it to ſuch a ſtate of diviſion, as to cauſe it to eſcape the ſight. It is ſufficient to exhibit the opinion; the more accurate and leſs hypothetical method of cultivating philoſophy, which is now univerſally adopted, will ſave us the trouble of confuting it.

Fifth Law of the Attraction of Compoſition.

When two or more bodies unite, by the attraction of compoſition, their temperature changes at the inſtant of their union.

This phenomenon has appeared ſo conſtantly to attend every operation that art can perform, that we have thought proper to conſider it as one of the laws of the attraction of compoſition. The temperature of bodies during combination, may be altered by the production of either heat or cold. The latter takes place much oftener than the former; but as cold is produced in many ſynthetical operations, we have expreſſed this phenomenon by the words "change of temperature."

It may be objected, that there are certain ſolutions or combinations ſlowly effected, in which no change appears. To this we anſwer, only by requeſting that they will plunge a very ſenſible thermometer in theſe ſolutions, and they will be convinced that a change of temperature takes place, which is almoſt always colder than that of the atmoſphere.

This phenomenon ſeems likewiſe to depend on the change of the aggregation of the ſubſtances that become combined, in their paſſage from ſolidity to fluidity, according to the obſervation of Baumé, of which we ſhall elſewhere ſpeak. But as this change of aggregation is a conſequence of the action of the attraction of combination, it is evident that this laſt attraction is the cauſe of the change of temperature.

M. Macquer was of opinion, that the variations in the temperature of bodies that enter into combination, depended on the motion the particles are put into; but if this explanation be admitted as ſufficiently indicating the cauſe of heat in caſes in which it is obſerved, it certainly does not explain other caſes, wherein cold is produced. Some modern chemiſts, and in particular Scheele and Bergman, are of opinion that heat, which they eſteem as a peculiar ſubſtance, is greatly concerned in chemical combinations, producing cold, when abſorbed; or heat, when diſengaged. This theory explains very well the changes of temperature that takes place when bodies unite.

Sixth Law of the Attraction of Compoſition.

Two or more bodies, united by the attraction of compoſition, form a ſubſtance, whoſe properties are very different from thoſe of any one of the bodies before their combination.

This law, in particular, requires to be well proved, becauſe many celebrated chemiſts of the preſent age have entertained notions reſpecting compounds, which by no means agree with the greater number of facts, and are directly oppoſite to what we here offer, as one of the principal and moſt remarkable of the phenomena attending the attraction of compoſition.

Stahl and his followers, whoſe abilities in other reſpects have been of ſuch important ſervice to chemiſtry, have affirmed, that compounds always partake of the properties of the bodies that enter into their compoſition; and that their properties are intermediate between thoſe of their principles. They have even carried this notion ſo far, as to imagine that it was poſſible to conjecture, from the properties of a compound, the nature of the bodies that compoſe it. From conſiderations of this kind it was, that Stahl pronounced ſalts to be compoſed of earth and water, becauſe, he thought, he obſerved in all ſalts, properties intermediate between theſe two ſubſtances. As we propoſe to diſcuſs this doctrine when we arrive at the part of our work that treats of ſalts, we ſhall make no obſervations on this example in this place, but ſhall content ourſelves with obſerving, that the chemiſts, who have followed Stahl in this opinion, have not had better ſucceſs than himſelf in their proofs; and that the intermediate or mean properties which they have pretended to diſcover in compounds, have ſeldom any but the moſt remote agreement with thoſe of the ſubſtances that conſtitute the combination. This obſervation we ſhall eſtabliſh from the conſideration of the very inſtances that are urged by Stahl himſelf. And we cannot here avoid remarking the difficulty which that author appears to have met with in eſtabliſhing this opinion in his writings, and the embarraſſment which prevails in his explanations. Theſe conſiderations engaged M. Bucquet and myſelf to examine this theory with attention, and induced us to adopt another directly oppoſite to it.

In reality, nothing more will be neceſſary to prove the exiſtence of the law concerning which we are now treating, than to point out inſtances of compounds, whoſe properties are entirely new, and have no kind of relation to thoſe of their component parts. The hiſtory of chemical combination tends to ſupport our poſition, and there is not a ſingle fact which will not furniſh matter for its proof.

To ſhow (1) that bodies which enter into combination loſe the properties they before poſſeſſed: (2) That they acquire new properties totally different; let us fix our attention upon ſuch properties, as if varied, will affect the ſenſes very conſiderably in conſequence of ſuch variation. The taſte is often very conſiderable in two ſimple bodies; and when they are combined, they have a very faint or feeble taſte when compared with that before poſſeſſed by either. Sulphat of potaſh, or vitriolated tartar, which is produced from the union of two ſtrong cauſtics, the ſulphuric or vitriolic acid, and pure potaſh, has only a bitteriſh taſte, which is certainly not an intermediate between the two cauſtic ſalts. On the contrary, two bodies that have little or no taſte, may acquire a very pungent one by their union. A few grains of oxygenated muriatic acid, diluted in a glaſs of water, and a few grains of mercury ſeparately given, are not capable of producing any noxious effect on the animal economy; while the ſame doſe of the oxygenated muriat of mercury, or corroſive ſublimate formed by the union of theſe ſubſtances, and adminiſtered in the ſame vehicle, is one of the moſt violent poiſons, and of a moſt corroſive taſte.

The attraction of compoſition, has a ſingular influence on the form. It often happens, that two matters, that are not ſuſceptible of cryſtallization alone, aſſume a regular form when they are united, as is the caſe with the muriatic acid gas, and ammoniac or alkaline gas, which, in the inſtant of their union, conſtitute cryſtals of muriat of ammoniac. In other caſes, the form is ſimply changed and modified, as in the union of certain neutral ſalts with each other, of ſulphur with metals, and in metallic alloys, which exhibit, according to Abbé Mongez, cryſtallizations ſomewhat differing from thoſe of the metals in a ſtate of purity. *Laſtly*, Bodies very ſuſceptible of cryſtallization alone, loſe this property when united with other bodies; as metals united with oxygen, and ſome of them when united with acids. We are obliged to make uſe of terms and denominations in this preliminary matter, which are yet unknown to the learner; but the index, and the commencement of the articles of the work to which the index refers, may be conſulted for the explanation of theſe words. This is an inconvenience which cannot be avoided in the elements of a ſcience.

The ſame obſervations, in proof of the law we offer, may be made with regard to conſiſtence. It is ſeldom the ſame in a compound, as in the principles that compoſe it. Thus it is found, that two fluids, united with each other, ſuddenly produce a ſolid, as is ſeen in a ſolution of potaſh added to ſulphuric acid in their concentrated ſtates; and that from the union of two ſolids, there frequently reſults a fluid, as in neutral ſalts combined with ice, and in the mixture of an amalgam of lead with an amalgam of biſmuth.

The colour is frequently altered in combination. Sometimes it diſappears, as when the coloured muriatic acid is added to a metal, the ſolution is tranſparent. Very often two bodies aſſume a deeper colour than before, in conſequence of their union; as when iron or copper are diſſolved in moſt acids, or lead, mercury, and moſt of the metals united to oxygen, and in the ſtate of metallic oxyds.

It is frequently found that two bodies of very pungent ſmell, form, by uniting, a ſubſtance without ſmell; as the muriatic acid gas, and ammoniac or alkaline gas, already mentioned, both which have a ſuffocating ſmell, but, in their union, form a neutral ſalt known by the name of muriat of ammoniac, which has ſcarcely any ſmell. Again, from inodorous bodies, a compound maſs ariſes, whoſe ſmell is ſtrong. Sulphur and fixed alkalis, which ſeparately have no ſmell, form livers of ſulphur, or ſulphures of alkalis, which are very fetid when moiſtened.

We may make the ſame obſervation with reſpect to fuſibility. Two ſubſtances which are very infuſible, or very difficult to fuſe ſeparately, become very fuſible when they are united; the combinations of ſulphur and of metals, afford very ſtriking examples of this aſſertion.

The foregoing facts are far from being the only ones which might be urged in ſupport of this law. There are many other that will offer, in the courſe of chemical reading, which it will not at all be difficult to apply.

Seventh Law of the Attraction of Compoſition.

The attraction of compoſition is meaſured by the difficulty of deſtroying the combination formed between two or more bodies[e].

Chemiſts are acquainted with methods of ſeparating bodies in combination with each other, whatever the degree of the adheſion or attraction may be; but theſe methods are more or leſs eaſy, and differ in their degree of complication or ſimplicity. In obſerving the appearances that take place in theſe proceſſes, it is conſtantly ſeen; that the more perfect the compound, the more difficult it is to ſeparate the principles, and deſtroy the compoſition. The degree of difficulty experienced in making this ſeparation, may, therefore, ſerve to ſhow the adherence, or attraction, that exiſts between bodies reſpectively.

We inſiſt the more ſtrongly on this law, becauſe it is eaſy for beginners to miſtake in eſtimating the difference of attraction that obtains among the ſeveral bodies they combine together. The rapidity with which certain bodies unite, may naturally produce a concluſion that the adheſion between them is very ſtrong. Long experience, however, has ſhown that this rapidity, ſo far from indicating the more perfect combinations, rather ſhows a weak adheſion, and produces only a very imperfect compound. In order, therefore, to fix with exactneſs the degree of affinity with which bodies combine and remain united, we muſt have recourſe to the meaſure of the difficulty experienced in ſeparating them; or deſtroying their union. The examination of the eight and laſt law will clear up this matter.

Eighth Law of the Attraction of Compoſition.

All bodies have not the ſame force of chemical attraction with reſpect to each other; and it is poſſible from obſervation, to determine the degree of the force exiſting between different bodies.

All bodies have not an equal tendency to combine with each other. There are ſome which abſolutely refuſe to unite, or at leaſt cannot be directly united by art, as iron and mercury, water and oil, &c.; though it would be falſe to aſſert, that there is no mutual attraction between them; other ſubſtances unite with difficulty, after a very long time.

But the moſt important circumſtance in the variety of chemical attraction, is, that as this force is not equal amongſt all bodies, it is practicable, from the knowledge and application of this phenomenon, immediately to effect the ſeparation of two bodies, whoſe union forms a compound. Bergman deviſed the name of elective attractions, to expreſs, that there is a kind of choice between thoſe bodies, which, in order to combine together, are decompoſed or ſeparated from matters before united with them. It is even certain, that the moſt eſſential part of the art of chemiſtry conſiſts in producing ſuch decompoſitions, by means of which, it works a kind of miracle in the eyes of ſuch as are unacquainted with them. To explain this, let us ſuppoſe two bodies to adhere together, with a force denoted by the number four, as for example, an acid and an oxyd, or metallic calx; and let a third body be preſented, which has an affinity to the acid equal to five or ſix, as for example, an alkali. What will be the conſequence? The alkali, which tends to unite with the acid, by virtue of a force ſuperior to that which joins the ſame acid to the metallic oxyd, muſt ſeparate the latter, in order to ſeize the acid. As this, in fact, takes place, the metallic oxyd is ſeparated, and a new combination is formed between the acid and the alkali. This decompoſition is denominated precipitation, becauſe the matter ſeparated commonly falls to the bottom of the fluid.

The matter that falls to the bottom is called a precipitate, and the ſubſtance added is called the precipitant. Precipitates may be diſtinguiſhed into four kinds. The true precipitate is formed, when one of the principles, ſuch as it exiſted in the compound, is ſeparated, and falls down. Thus, when ſulphat of lime, formed by the combination of the ſulphuric acid and quick-lime, is decompoſed by the addition of potaſh, which has a greater affinity with the acid, the lime is ſeparated, and, falling to the bottom, conſtitutes a true precipitate. There is a falſe precipitate obtained, when the new combination, formed between the precipitant or ſubſtance added, and one of the principles of the compound, falls to the bottom by reaſon of its inſolubility, and the ſeparated matter remains in ſolution. Thus, in decompoſing the nitrat of mercury, by the muriatic acid, with which the oxyd of this metal has more affinity than with the nitric acid, the new combination of mercury and muriatic acid falls to the bottom of the veſſel, forming a falſe precipitate, above which the nitric acid remains diſſolved in the water. This difference depends only, as we ſhall ſee elſewhere, on the difference of ſolubility of the matters.

It may eaſily be ſeen, that the erroneous denomination of this laſt example tends to miſlead beginners. It is certain that thoſe who gave the name of precipitate to the ſubſtance ſeparated from the compound by the precipitant, ought not to have applied it alſo to the new combination produced in the latter caſe. But even ſuppoſing that the name precipitate were confined to the matter ſeparated by the precipitant, it would ſtill be productive of error, becauſe there are many caſes in which the ſeparated matter, ſo far from falling to the bottom, riſes and is volatilized. This happens when the combination of muriatic acid, and ammoniac or volatile alkali, known by the name of muriat of ammoniac, is decompoſed by quick-lime, which has a greater affinity to the acid than the volatile alkali has; the latter flies off in vapour, and no precipitate is found in the mixture.

It is ſufficiently clear, that a liquid muſt be preſent in the operations that afford the precipitates we have ſpoken of. In this caſe, the precipitation is ſaid to be effected in the humid or moiſt way, in order to diſtinguiſh it from that which is made in the dry way, or by fire, and which is effected either by fuſion or diſtillation; operations that will be explained at length in the following part of this work.

Modern chemiſts have likewiſe diſtinguiſhed, with much more propriety, two other kinds of precipitates. Theſe are pure and impure precipitates. The firſt comprehend all bodies which, after having been ſeparated from the compounds of which they were before a part, regain all their former properties, and appear to have ſuffered no alteration, either in conſequence of their having entered into a combination, or of their ſubſequent ſeparation. The number of this kind of precipitates is very conſiderable, though that of the impure kind is ſtill greater.

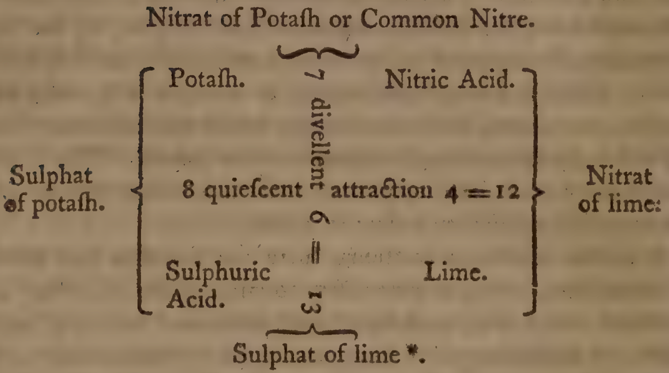
That a precipitate may be very pure, it is neceſſary, not only that it ſhall have ſuffered no change in becoming part of a compound, but likewiſe that it ſhall have no affinity with the precipitant. For example, when ſpirit of wine is poured on a ſolution of ſulphat of potaſh in water, the ſpirit of wine, which has more affinity with the water than it has with the ſalt, ſeparates the latter; and the ſulphat of potaſh falls down in a ſtate of purity, becauſe it has ſuffered no alteration from the water it was combined with, nor with the ſpirit with which it cannot unite. But if two bodies are mutually altered in their union, as is the caſe when metals are combined with acids, then the third body employed to ſeparate them, as for example, an alkali, will precipitate the metal in a ſtate widely different from that which is natural to it, and by that means exhibits an impure precipitate. The ſame thing happens, if the precipitant has any tendency to unite with the precipitate; as in the example already cited of a metallic ſolution decompoſed by an alkali, a part of this laſt ſalt may combine with the metallic oxyd, and render it impure. Theſe two cauſes of the impurity of precipitates are almoſt always united. In ſome caſes there is a certain method of immediately diſtinguiſhing an impure from a pure precipitate; it conſiſts in adding a much greater quantity of the precipitant than is neceſſary to deſtroy the combination; and the exceſs, by combining with, and diſſolving the precipitate, will cauſe it to diſappear. By pouring ammoniac or volatile alkali on a ſolution of copper in the nitric acid, the copper is precipitated in the form of flakes, of a light blue colour. The colour of this precipitate, far from reſembling the metallic brilliancy of copper, immediately ſhows it to be an impure precipitate. This is ſtill more confirmed by the addition of more ammoniac. This ſalt diſſolves again the blue precipitate; the liquor gradually reſumes its tranſparency, and aſſumes a beautiful blue colour, which indicates the combination of the oxyd of copper with the volatile alkali.

The exact knowledge of theſe impure precipitates, which preſent themſelves much more frequently than the pure, is due to the reſearches of M. Bayen on the decompoſition of mercurial ſolutions by alkalis, and the ſtate of the precipitates obtained in theſe operations. After the foregoing explanations, it will not be at all difficult to underſtand the theory of decompoſitions, as effected by the addition of a third body to a combination of two decompoſitions which are produced in conſequence of ſimple elective attractions.

Beginners will not find the ſame facility in underſtanding what paſſes in the more complicated phenomena called by chemiſts double elective attractions. It often happens, that a combination of two bodies cannot be deſtroyed by a third or a fourth body ſeparately, though if a compound of the two laſt were preſented to the former, a mutual decompoſition would take place. An example will render this clear. Sulphat of potaſh, or the combination of the ſulphuric acid with potaſh, cannot be decompoſed either by the cold nitric acid, or by lime, if preſented ſingly; but if to a ſolution of this neutral ſalt, be added the neutral ſalt formed by the union of the nitric acid and lime, the two combinations are mutually decompoſed; the nitric acid ſeizes the potaſh and forms nitre, while the ſulphuric acid uniting with the lime, forms ſulphat of lime; which, being much leſs ſoluble than the nitre, falls to the bottom. The explanation of this remarkable phenomenon is as follows. The ſulphuric acid, united with potaſh, cannot be decompoſed by the nitric acid, nor by lime; becauſe its affinity with the alkali is greater than that of the nitric acid or lime, either to itſelf, or to the alkali: But when we add to ſulphat of potaſh a compound of nitric acid and lime, the nitric acid tends to unite with the potaſh, at the ſame time that the ſulphuric acid tends to combine with the lime; hence we may ſay, that the decompoſition of ſulphat of potaſh, begun by the nitric acid, is completed by the lime. To render this ſtill clearer, let us aſſume numbers to expreſs the forces. Suppoſe the ſulphuric acid to adhere to the alkali, with a force denoted by 8; the nitric acid tends to unite with the alkali with a leſs force, which therefore we may call 7; and therefore cannot ſingly effect the decompoſition. Again, If, on the other ſide, the tendency of the lime to unite with the ſulphuric acid be aſſumed, for the ſame reaſon, to be 6, it will, with the former, conſtitute a force equal to 13, which will overcome that by which the ſulphuric acid adheres to the potaſh. This compound force muſt alſo be greater than that which retains the nitric acid, and lime, in a ſtate of union.

In double elective attractions, there are therefore two kinds of attractions, which it is neceſſary to diſtinguiſh. 1. That by virtue of which the principles of each compound adhere to each other. It is this degree of force, which, in the inſtance adduced, retains the ſulphuric acid, in union with the potaſh, and which cauſes the nitric acid to adhere to the lime. With Mr. Kirwan I ſhall call this force the *quieſcent attractions*, becauſe it tends to preſerve the union of the four principles in their original form. 2. That by virtue of which the four principles change their order, and form new combinations. In the inſtance cited, the potaſh unites with the nitric, and the lime with the ſulphuric acid. I ſhall call this force the *divellent attractions*, becauſe it is capable of deſtroying the effect of the former. By the help of this uſeful diſtinction, we may very eaſily ſhow what happens in the decompoſition and new combinations by double affinity, by forming a table after the manner of Bergman. For this purpoſe, the two compounds, that mutually decompoſe each other, are to be placed between two braces oppoſite each other, ſo that the acids may be oppoſed to the baſes they exchange; and by adding together the numbers expreſſing the force of the attraction the four bodies have for each other, the two horizontal numbers will give the ſum of the quieſcent attractions, while the two vertical numbers will exhibit the divellent attractions by which they are oppoſed. If the ſum of the latter exceeds that of the former, a double decompoſition and combination will follow. By applying the method to the preceding example, its utility and preciſion will be eaſily ſeen.

EXAMPLE.



Chemiſts have not, till very lately, attended to the double elective attractions; and the inſtances wherein they take place are far from being all known. They who employ themſelves in chemical reſearches, will continually obſerve this kind of decompoſition in circumſtances where no ſuch event has been ſuſpected. Many occaſions will preſent themſelves in the hiſtory of ſaline matters, in which we ſhall obſerve theſe double elective attractions as lately diſcovered by Bergman, Scheele, &c. and ourſelves[f].

We cannot quit the explanation of this eighth and laſt law of the attraction of compoſition, without taking notice of the ingenious method, firſt contrived by a French chemiſt, to exhibit at one view, the leading phenomena of chemical decompoſition. Geoffroy the elder, paying greater attention than his predeceſſors to the various relations between chemical bodies, and the precipitations they occaſion, contrived, in the year 1718, to repreſent in a table, in the order of their affinities, ſuch bodies as he had obſerved. We confine ourſelves to the ſimple mention of this happy thought in this place, which we ſhall have many opportunities of explaining in the courſe of the preſent work. Geoffroy offered his table to the public, as an eſſay to which he foreſaw it would be neceſſary to make great additions and alterations. Many chemiſts have adopted and extended his plan. Rouelle the elder made ſome corrections in his table, and added ſeveral columns. M. de Limbourg, a phyſician at Spa, in an excellent diſſertation, which gained, in conjunction with M. Sage of Geneva, the prize pro-

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* I have explained ten examples of double decompoſitions that take place in mixing neutral ſalts, in my Memoirs et Obſervations de Chimie, Vol. I. p. 308 and 438.

poſed in 1758, by the academy of Rouen, has conſtructed a table of ſtill greater extent. Gellert, in his Metallurgic Chemiſtry, has alſo given a new one. But no one has advanced this part of chemiſtry more than M. Bergman, profeſſor of chemiſtry at Upſal. This celebrated chemiſt has made a diſtinction between the attractions, like Baumé, that take place in the dry and humid way. He has given two very large tables, in which he ſhows the elective attractions which exiſt among a conſiderable number of bodies. We are likewiſe indebted to the ſame philoſopher for a very ingenious table, in which he has found means, by a peculiar diſpoſition of the chemical characters, to preſent a view of the phenomena of double elective attractions; of which an example has juſt been given [g].

[h] After having thus exhibited the principal phenomena of chemical attraction, and eſtabliſhed the laws by which this force appears to be governed, we ſhall proceed to take notice of certain caſes in which theſe laws ſeem to be ſubject to variation. We ſhall not here enter into a detail of the facts on which this aſſertion is grounded, becauſe it is our intention to remark them carefully wherever they occur. We ſhall, therefore, only obſerve, that the apparent inconſtancy of the laws of chemical attraction depends ſolely on certain modifying circumſtances; as the quantity of matter, the temperature of the atmoſphere, motion or reſt, ſolution by water or by fire, that is, by the humid or dry way, the particular ſtate of aggregation, &c. Bergman has conſidered all theſe circumſtances with ſingular care and attention, and has explained the various apparent changes they are capable of producing in the laws of attraction. And from the whole of the facts which he has collected on this ſubject, he has concluded that theſe variations ought not to be regarded as exceptions, and are by no means ſufficient to weaken the evidence on which the doctrine of chemical attractions is founded.

This ſhows the opinion which ought to be entertained of two other kinds of affinity admitted by certain authors. The one is the affinity of intermedium, and the other the reciprocal affinity. By the firſt, they underſtand that which cauſes a body in combination with another to unite with a third, though it would not have united with this laſt, if it had not previouſly been combined with the former. Oil, for example, will not unite with water; but where the oil is combined with a ſalt, a ſoap is produced ſoluble in water, by the medium of the ſaline matter. It is not, however, the ſalt that renders the ſoap ſoluble, becauſe it does not exiſt in the combination with all its ſaline properties; but it is to the new properties of the compound ſoap, that its ſolubility in water is to be referred. This phenomenon is entirely dependent on the ſixth law of chemical attraction, which declares, that compounds poſſeſs properties entirely new and different from thoſe of their component parts[i].

The reciprocal affinity takes place when a compound of two bodies is decompoſed by a third, and the ſeparated principle is capable of decompoſing the new combination in its turn; ſo that there ſeems to be a ſort of reciprocity in the effects. So, for example, it is found that the ſulphuric acid has a greater affinity with the potaſh, than the nitric acid has, and that it decompoſes the combination of this alkali with the latter acid. Nevertheleſs, the nitric acid can, in its turn, ſeparate the ſulphuric acid from the alkali, ſince it is certain, that by heating ſulphat of potaſh with nitric acid, nitre is again formed. This kind of affinity admitted by M. Baumé, is to be attributed ſolely to the circumſtances that produce a change in the forces. Theſe are heat, and the ſtate of the nitric acid, for it is in fact neceſſary that the nitric acid ſhould be hot, to decompoſe ſulphat of potaſh; and the nitre formed in this operation is again decompoſed by the ſulphuric acid, when the mixture becomes cold. The fuming or *nitrous acid* decompoſes ſulphat of potaſh in the cold; fuming ſpirit of ſalt or muriatic acid, effects the ſame decompoſition according to the obſervation of M. Cornette; but Bergman has with great reaſon obſerved, that the odorous and fuming acids have other affinities than the ſame acids ſimple; beſides there is only a ſmall part of the ſalts decompoſed[k].

In every caſe of this kind, the order of the elective attractions is changed and modified by particular circumſtances. The other facts whereon Baumé founds his proof of the reciprocity of affinities, as the decompoſition of muriat of ammoniac by lime, and of the muriat of lime by *concrete volatile alkali*, belong to the double affinities, as we ſhall ſhow when we come to ſpeak of theſe ſalts.

Nothing remains at preſent to conclude our diſcourſe on chemical attraction, but to exhibit the opinions of ſome philoſophers on the cauſe of this force.

Thoſe philoſophers, who firſt attended to the ſubject, attributed it either to the ſimilar figure of the elementary molecules, or the phyſical configuration of the parts; or laſtly, to a certain occult relation of their intimate compoſition. Theſe early notions are neceſſarily connected with the mechanical explications that embarraſſed the ſcience of natural philoſophy in its infancy.

The greater number of ſuch modern philoſophers, as have endeavoured to explain the cauſe of the attraction of compoſition, have obſerved a remarkable analogy between this force and the Newtonian attraction. Perſuaded that nature is ſimple and uniform, they concluded that the property of mutually uniting muſt depend on that of attraction, which all bodies are known to poſſeſs. They have formed a compariſon between the ſmall chemical bodies which are acted on by the affinities, and the large maſſes that compoſe the univerſe; and have conſidered the approach of the former to each other to combine, as a conſequence of their mutual gravitation. It is by adopting and modifying this opinion, that certain writers have concluded that the force of chemical attraction follows the ratio of the weight, and that the heavieſt body poſſeſſes the power of combination in the ſtrongeſt degree. This hypotheſis ſometimes agrees with facts *, as may be obſerved with regard to many acids; but it cannot be reconciled to a great number of decompoſitions, particularly thoſe of metallic ſubſtances. Laſtly, Some chemiſts have been ſo firmly perſuaded, that there is the moſt perfect relation between attraction and chemical affinity, that they have imagined it poſſible to meaſure and compute its force from the adheſion that takes place between bodies M. de Morveau, whoſe opinion is of ſuch authority as to lead that of other philoſophers, has made ſome experiments with a view to prove this aſſertion. Theſe experiments conſiſted in applying to the ſurface of mercury, metallic plates of equal dia-

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* This hypotheſis cannot be brought to the teſt of experiment, and muſt therefore reſt, like many others, entirely on its analogy with the phenomena that ſuggeſted it. The force of affinity may depend on, or be proportional to, the ſpecific gravity of the particles; but that ſpecific gravity has no ſort of relation to, and conſequently is not deducible from, the ſpecific gravity of the aggregate. To mention one, among innumerable inſtances, in proof of this aſſertion; it is found that fixed air compoſes more than one third of the weight of calcareous ſpar, whoſe denſity is nearly three times that of water; but when diſengaged, occupies many hundred times the former ſpace. Can the ſpecific gravity of its particles be inferred from either ſtate? Certainly not. T.

meter, ſuſpended from the arm of a balance, whoſe other extremity carried a diſh as uſual. In this laſt he placed weights, till their force became equal to the ſeparation of the metallic plate from the ſurface of the mercury; and he found, by comparative trials with different metals, that their adherence to the mercury was various, and agreed ſufficiently near with their affinities with that fluid. That is to ſay, he found that gold adhered the ſtrongeſt of all to the mercury, while cobalt, which is ſcarcely capable of uniting with it, was raiſed very eaſily from its ſurface, with which it has little or no adheſion. We muſt here take the liberty of obſerving, that experiments of this nature are ſubject to error; becauſe the lower ſurface of the metal muſt combine with the mercury; and the portion of amalgam formed in theſe circumſtances, being naturally more conſiderable where the metal unites the moſt readily with the mercury, will then add moſt to the weight, and conſequently require the greateſt force to lift it up from the ſurface of the mercury. A plate of metal which adheres to the ſurface of mercury cannot be taken up without ſeparating the latter into two ſtrata; ſo that the weight neceſſary to raiſe the plate is employed in overcoming the adheſion of the particles of mercury to each other, rather than in deſtroying that of the foreign metal with the mercury [l].

We may therefore affirm, that if the chemical attraction be the ſame force with the general attraction, the difference of its laws, compared with thoſe of this laſt, ſhows that it is a peculiar modification. This truth may be eaſily aſcertained, by comparing the knowledge we poſſeſs concerning the attraction admitted by Newton, with that which we begin to have concerning chemical attractions. In reality, the former does not ſenſibly ſhow itſelf, but between large maſſes, and is in the direct ratio of the quantities of matter; whereas the latter is not obſerved, but between very minute bodies, and is abſolutely inſenſible when the bulks are conſiderable. The former exerts its power at immenſe diſtances; but the latter does not exiſt but between bodies in contact, or nearly ſo [m]. We have already exhibited a part of the compariſon, in examining the laws of the chemical force we are inquiring into; and we believe, after all theſe reflections, that the difference between theſe two natural phenomena is ſufficiently marked to render it incumbent on philoſophers to make a diſtinction between them.

NOTES ON CHAPTER III.

[Page 107.]

[a] Mr. Kirwan, in the courſe of his intereſting inquiry concerning the attractive powers of the mineral acids, has drawn the line of diſtinction between chemical affinity and thoſe other powers of matter to which it has the greateſt reſemblance. The inſertion of his remarks upon the ſubject may not be unacceptable or unuſeful to the reader, ſince Fourcroy has neglected to give a diſcriminative character of chemical affinity.

"Chemical affinity or attraction, Mr. Kirwan obſerves, is that power by which the inviſible particles of different bodies intermix and unite with each other ſo intimately, as to be inſeparable by mere mechanical means. In this reſpect it differs from magnetic and electrical attraction. It alſo differs from the attraction of coheſion * in this, that the latter takes place betwixt particles of almoſt all ſorts of bodies whoſe ſurfaces are brought into immediate contact with each other; for chemical attraction does not act with that degree of indifference, but cauſes a body already united to another, to quit that other and unite with a third; and hence it is called *elective* attraction." (Philoſophical Tranſactions for 1783, p. 35.)

[b] Morveau has very properly pointed out the inaccuracy of this expreſſion. The affinity of compoſition does not become *ſtronger* as the affinity of aggregation becomes *weaker*; it becomes more *efficacious* only; the abſolute power remains the ſame; the effect produced by that power increaſes, becauſe the reſiſtance oppoſed to it is leſſened. It is farther obvious, that in eſtimating the force which the affinity of aggregation oppoſes to chemical union, we ſhould conſider it in exactly the ſame light as any other *quieſcent* affinity.

[c] This law of chemical affinity has been rejected by Morveau, as conveying an incorrect notion of what occurs in the caſes of chemical combination to which it refers. "It frequently happens, he obſerves, that three ſeparate bodies, meeting in a fluid ſtate, unite and form a ſingle maſs, which has all the characters of a homogeneous compound, and which retains this character, till its compoſition has been altered by chemical means. Such, for example, is the alloy of gold, ſilver, and copper. It has been ſaid, that this triple compound is formed by what has been called *complicated affinity*; but this kind of expreſſion ſerves only to divert the mind from taking a juſt view of the experiment. It is not the ſimultaneous and reciprocal action of the three metals on one another, that is eſſential to the ſucceſs of the experiment; we have this proof of it, that preciſely the ſame alloy is obtained, whether the gold be firſt united to the ſilver or to the copper, or though the copper be firſt united to the ſilver. We have, therefore, two ſucceſſive combinations during the experiment. In the firſt of theſe, a particle of one of the metals comes into contact, and unites with a particle of one of the other metals; and, in the ſecond, this newly formed compound unites to a particle of the third

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* Mr. Kirwan inadvertently uſes the term of *coheſion* in the ſenſe which is more properly expreſſed by the term of *adheſion*. By coheſion is meant the force which unites together particles of the ſame nature, and forms them into a more or leſs reſiſting maſs; and in this ſenſe coheſion is nearly ſynonymous with the affinity of aggregation, while adheſion denotes the force by which the ſurfaces of different bodies are held together.

metal, in conſequence of the affinity which, as a compound, it acquires for that metal. There is nothing peculiar or extraordinary in this. We have, as in other caſes, two chemical forces acting in ſucceſſion, and two ſucceſſive combinations formed."

"What has been ſaid of the alloy of three metals, may be applied to all ſimilar caſes, whatever be the nature or the number of the ſubſtances employed." See article *Affinity* of the chemical part of the *Encyclopédie Méthodique*, page 550.

[d] Nothing can be more certain than that every chemical compound poſſeſſes properties, which are in ſome reſpect different from thoſe of its immediate conſtituents, and which cannot be ſaid with any meaning to poſſeſs a middle nature between the properties of theſe conſtituents. But we are not on that account to imagine, that compounds uniformly differ in all their chemical properties from their conſtituents, as the expreſſions of Fourcroy would ſeem to imply. The contrary is frequently the caſe. The ſaturated carbonates of potaſh, ſoda, ammoniac, &c. act upon the vegetable colours in the ſame manner that the pure alkalis do. The acidulous tartrite of potaſh is a regular compound, its conſtituents having a determinate degree of ſaturation, and yet it reddens the vegetable colours as the ſame acid would have done. Ammoniacal ſalts participate, in general, in the volubility of their baſe. We are not, therefore, to deny the reality of compounds exhibiting in ſome reſpect the ſame character with their conſtituents. It is enough to diſtinguiſh them as different ſubſtances, that the compound poſſeſſes ſome one chemical property, differing in nature or in degree from any property of its conſtituents, or from any combination of their ſeparate properties.

[e] This enumeration is obviouſly not a law of chemical affinity, but a truth of definition.

[f] In every caſe where more than three bodies are required for the production of any chemical change, we are to conſider the change as depending not on ſimple affinities, or on the independent affinities of ſingle bodies to one another, but upon the ſum of all the affinities that concur in tending to the ſame end. To illuſtrate the principle, that in double elective attractions, the condition by which decompoſition is determined, is the relative ſum of the divellent and quieſcent affinities, and not the ſtrength of any ſingle affinity in particular, it may be proper to give an inſtance in which no decompoſition takes place, when two ſubſtances are uſed together, though either of them could have effected it if employed ſeparately. The acetite of lime is decompoſed by ſoda; it is alſo decompoſed by the muriatic acid; yet it reſiſts the action of the muriat of ſoda. The following table will illuſtrate this.

$$\begin{array}{c}\text{Acetite}\\ \text{of}\\ \text{lime.}\end{array}\left\{\begin{array}{ccc}\text{Acetous acid} & 25 & \text{Soda}\\ 19 & + & 28 = 47\\ \text{Lime} & \underline{20} & \text{Muriatic acid}\\ & = 45 & \end{array}\right\}\begin{array}{c}\text{Muriat}\\ \text{of}\\ \text{ſoda.}\end{array}$$

In this inſtance the affinity of ſoda with the acetous acid is greater than the affinity of lime with the acetous acid; and the affinity of the muriatic acid with lime, is greater than the affinity of the acetous acid with lime; but the ſum of the quieſcent affinities is greater than the ſum of the divellent affinities, and therefore no decompoſition takes place.

In many caſes of chemical mixture, the affinities of more than four ſubſtances are concerned; and though ſuch caſes are of the ſame nature with thoſe of double elective attraction, yet that term ſeems inapplicable to them, as it implies the agency of only four ſubſtances. Morveau has, therefore, ſubſtituted the language of *concurrent affinity (affinité par concours)*, as the general expreſſion for that tendency to chemical combination, which is rendered efficacious by the conjoined operation of more affinities than one. It is probable that this expreſſion will be adopted in the place of Bergman's, which is evidently too reſtricted in its literal application.

It may farther be obſerved, that in every chemical combination which is preceded by decompoſition, the divellent and quieſcent affinities muſt be equally attended to, in order to form a proper eſtimate of the experiment; for the quieſcent affinities, even when they cannot prevent decompoſition entirely, are ſtill able to diminiſh the promptitude with which it takes place, and frequently to ſtop its progreſs at a lower point of ſaturation than the *divellent* ſubſtance would otherwiſe require. It will alſo happen, on ſome occaſions, that the concurrence of ſeveral divellent affinities, though not abſolutely neceſſary to produce a particular effect, will yet accompliſh it more completely, and with greater facility, than any of them ſingly could have done.

[g] See Appendix.

[h] The laws of chemical affinity propoſed by Morveau *(Encyclopédie Méthodique)* are ſomewhat different from thoſe enumerated by Fourcroy. The following are additional.

I. He ſhows, by a variety of inſtances, that when two bodies are preſented to one another, the ſaturated compound which reſults from their union is capable of combining with an exceſs of one of its conſtituents; but the affinity which produces this laſt combination is not the ſame with the affinity which unites together the conſtituents of the compound itſelf; nor has it any known ratio to this latter affinity, but appears in every caſe to be very much inferior to it in ſtrength. The following is an appoſite illuſtration of theſe facts and inferences. The ſulphat of barytes is one of the ſtrongeſt combinations in chemiſtry, and one of the moſt perfect neutral ſalts. When the concentrated ſulphuric acid is boiled over this ſalt, a conſiderable quantity of it is diſſolved by the acid, and this quantity is inſtantly precipitated by the addition of water. We have in this caſe a ſaturated compound (the ſulphat of barytes) uniting with an exceſs of the ſulphuric acid, but forming with it a combination infinitely weaker than the ſulphat of barytes, ſince it is decompoſed by the ſingle affinity of the ſulphuric acid with water.

The following caſe will ſerve as another example of a compound uniting with an exceſs of one of its conſtituents, and at the ſame time will explain an apparent exception to the ordinary laws of chemiſtry. It is known that the ſulphuric acid has a greater affinity with potaſh than the nitric acid has. Yet Baumé, having diſſolved the ſulphat of potaſh in an equal weight of the nitric acid, obtained, after filtrating and evaporating the liquid, a conſiderable quantity of cryſtallized nitrat of potaſh. In this curious experiment there is a part only of the ſulphat of potaſh decompoſed, and what remains is combined with an exceſs of acid. From theſe data, and from analogous experiments with the muriatic and tartarous acids, Morveau has conſtructed the following table, to explain in what manner part of the ſalt is decompoſed.

Nitrat of potaſh.

Nitric acid.	58	Potaſh ſaturating about one third of the neutral ſalt.
2	+	62 = 64
Sulphat of potaſh which remains undecompoſed.	34 — = 92	Sulphuric acid ſaturating the ſame quantity of the ſalt.

Sulphat of potaſh with an exceſs of acid.

To take but one other example:—Morveau procured oxalate of lime, by adding lime-water to the oxalic acid; the liquor was ſtill manifeſtly acid; he ſeparated the oxalate, poured a little diſtilled water upon it, to carry off any uncombined acid which might be adhering to it, and having placed it to digeſt in the ſyrup of violets, he found, at the end of a few hours, that the ſyrup was quite green. We have, in this inſtance, the example of a compound uniting with an exceſs of one of its conſtituents, though an exceſs of the other was preſent.

Farther illuſtrations of this principle will be found in the valuable eſſay of Morveau, ſo frequently referred to.

II. Chemical affinity is influenced by temperature; its action being accelerated, retarded, prevented, or rendered efficacious, according to the degree of the temperature.

There are two caſes in which temperature modifies the action of chemical affinity.

In the one, the compoſition of bodies is changed, in conſequence of the different affinities of their conſtituent parts with caloric, at different temperatures. Let the affinity of A with B=6, and its affinity with C=5; and let A and C be very fixed ſubſtances, or at leaſt much leſs volatile than B; it is evident that A will unite with B at the common temperature of the atmoſphere. But if we continually augment the temperature of the three bodies, the tendency of B to the ſtate of vapour will increaſe in a faſter ratio than that of the other two, till at length this tendency, in addition to the affinity of C with A, will overcome the oppoſing affinities, B will eſcape in the ſtate of vapour, and C will combine with A. Obvious examples of this mode of influencing affinity by means of temperature, occur in every part of chemiſtry.

2. But there are caſes where the accumulation of caloric appears to be a condition eſſentially requiſite to determine bodies to unite, without the caloric combining with any principle ſeparated from theſe bodies at the inſtant of their union, or remaining in combination with the new compound formed. This happens particularly in caſes of combuſtion. Every one knows, that either a very high temperature, or an ignited ſpark, is neceſſary to diſpoſe hydrogenous gas to combine with the oxygen of atmoſpheric air or oxygenous gas. In the ſame manner charcoal, ſulphur, phoſphorus, &c. require a certain temperature for their combuſtion, and this temperature varies according to the condition of the oxygen preſented to them. Some of theſe bodies, phoſphorus in particular, burn at different temperatures, but with very different phenomena.

Theſe effects of temperature upon the affinities have been expreſſed in a general form by Morveau; but he has not attempted to give any rationale of their cauſe; nor indeed has any ſatisfactory explanation of them been given. From ſome curſory obſervations made by Berthollet, in an Eſſay on the Combination of Metallic Oxyds with Alkalis and Lime, publiſhed in the *Mem. de l'Acad.* 1788, it would appear, that, together with Monge, he conceives that this effect of caloric may be generalized, by aſſimilating it with the operation of mechanical preſſure in producing certain chemical combinations. Dr. Higgins has alſo propoſed an hypotheſis on the ſubject. See Minutes of the Society for Philoſophical Experiments and Converſations.

i Two ſubſtances may have an affinity for each other, and yet there may be ſome condition wanting, which is neceſſary for their chemical combination. Acids do not unite with alkalis, unleſs the one or the other be diſſolved in water. Metals do not form alloys with one another, unleſs in the ſtate of fuſion. Metals are not ſoluble in acids, unleſs they be previouſly oxydated; and ſome metallic oxyds, thoſe of iron and manganeſe for example, are capable of uniting with an exceſs of oxygen, ſo as to be rendered a ſecond time inſoluble in acids. To procure a chemical union in theſe caſes, it is neceſſary to diſſolve the acid or alkali in water; to reduce the metals to the ſtate of fuſion; to oxydate the metals that are to be combined with acids; and to diſoxygenate in part thoſe oxyds which have received an exceſs of oxygen. But when ſubſtances have an affinity for one another, and are prevented from combining together, as in theſe inſtances, by the abſence of ſome condition neceſſary for their union, Morveau applies the term of *affinité diſpoſée*, to expreſs the change that takes place in the operation of their affinities when the obſtacle to their union is removed. The uſe of this term may be illuſtrated from an explanation that has been given of the facility with which iron diſſolves in the diluted ſulphuric acid. It is neceſſary to mention that iron, like the other metals, is inſoluble in acids, unleſs previouſly oxydated. It is alſo neceſſary to obſerve, that iron decompoſes water ſlowly at the common temperature of the atmoſphere; but when a little ſulphuric acid is added to the mixture of water and iron, the water is then decompoſed rapidly, and an oxyd of iron formed, which is immediately diſſolved by the acid. But upon what principle does the ſulphuric acid accelerate the decompoſition of the water, ſince it is incapable of uniting with the iron till the latter has already decompoſed the water, and acquired the ſtate of a black oxyd? We anſwer, that the iron, in its metallic ſtate, has an affinity with the ſulphuric acid; that this affinity is indeed incapable of producing combination, becauſe the iron, in its metallic ſtate, cannot unite chemically with any acid; but this affinity, ſuperadded to the affinity which the iron has for the oxygen of the water, increaſes the ſum of the divellent powers that concur in producing the ſame ſeries of chemical effects. The affinity of the acid with the iron, and the affinity of the iron with the oxygen of the water, tend to the ſame common end, and therefore favour each others operation. The affinity of the iron with the acid is unable to produce combination; we muſt have the *affinity rendered efficacious* (*the affinité diſpoſée* of Morveau); we muſt have the iron oxydated. This is accompliſhed by the concurring affinities of the iron with the acid, of the iron with the oxygen of the water, and of the acid with the oxygen of the water, as forming a neceſſary conſtituent of the metallic oxyd.

It would appear, then, that the term of *affinité diſpoſée* may be retained in chemiſtry, as the general expreſſion for the effect of thoſe changes in the condition of bodies; in conſequence of which, their previouſly exiſting affinities are enabled to unite them chemically, and without which their union is impoſſible. The *affinité diſpoſée* includes, as a more comprehenſive expreſſion, what has been called the *affinity of intermedium*. It is obvious that the criticiſm in the text will not apply to the generality of caſes. It is true, that the ſulphat of iron is ultimately formed in conſequence of the affinity of the ſulphuric acid with the oxyd of iron; but how are we to explain the rapid oxydation of the iron, without a previouſly exiſting affinity between the acid and iron, in its metallic ſtate; and why not a general expreſſion, for the effect produced by the removing of thoſe obſtacles in the preſent condition of a body, which prevent its affinity for another body from accompliſhing their union.

k The anomalous appearances which had ſuggeſted to Baumé and Cornette the idea of *reciprocal affinity*, have been accounted for, on the received principles of chemiſtry, by Bergman and Berthollet; and their explanations have been adopted by Morveau, who has inſerted them, together with ſome valuable ſpeculations of his own, in the article *Affinity*, of the *Encyclopédie Méthodique.* It was intended to have given an abſtract of his remarks upon the ſubject; but, on farther reflection, it was thought that the length and minuteneſs of the diſcuſſion did not ſuit with the nature of an elementary work.

l Theſe objections to Morveau's experiments, it may be obſerved, are rather ſpecious than ſolid. For, in the *firſt* place, the quantity of amalgam formed during the ſhort time that the metals are in contact, is too inconſiderable, to counterpoiſe the weights which are found neceſſary to break the adheſion of the mercury with the metallic plates; and, in the *ſecond* place, if theſe weights meaſured the adherence of the particles of the mercury among themſelves, it is evident that, after making proper allowance for the ſmall quantity of amalgam really formed, the ſame weight ſhould, in every inſtance, overcome the adheſion, and the nature of the metallic plate employed, ſhould have no farther influence upon the reſult. The imperfection in Morveau's theory, of obtaining data for calculating the affinities, from the forces with which different bodies adhere together, conſiſts principally in the difficulty, if not impoſſibility of applying his method to a ſufficient variety of ſubſtances.

m It cannot be ſaid that the compariſon made by Fourcroy, tends much to elucidate the queſtion which he has ſubmitted to his readers. For, in the *firſt* place, ſo far is the Newtonian attraction from being conceived to act upon enormous maſſes only, that it is a principle of the Newtonian philoſophy, that every particle of matter gravitates towards every other particle of matter; and, in the *ſecond* place, what is called by Fourcroy contact, is in truth only a ſmaller diſtance. The views entertained by the moſt philoſophic of the modern chemiſts, upon this intereſting ſubject, are too remote from immediate application, to find a place with any propriety, in an elementary work. They will be found in Bergman's *Opuſcula*, in Macquer's *Dictionnaire de Chimie*, article *Peſanteur*, and in the article *Affinity*, of the chemical part of the *Encyclopédie Méthodique.*

CHAPTER IV.

CONCERNING THE PRINCIPLES OF BODIES.

PHILOSOPHERS in every age have admitted, that all the variety of natural bodies are formed of primary ſubſtances, more ſimple than themſelves, which they have diſtinguiſhed by the name of principles. Chemiſts, who have the ſtrongeſt conviction of this leading truth from their analyſes, have formed ideas, ſufficiently preciſe, of the nature and difference of theſe principles; and have even admitted of ſeveral kinds or claſſes. It muſt, however, be remarked, that they uſe the word principle in a different ſenſe from that adopted by the ancient philoſophers. For Ariſtotle and Plato did not regard any ſubſtances as principles, but ſuch as are too minute to be perceived by the ſenſes, and form, by their aſſemblage, bodies ſomewhat leſs ſimple, which are within the ſphere of perception, and were by them called elements; a name ſtill retained, and applied in the ſame ſenſe. Theſe are what other philoſophers have called atoms, or monades. But chemiſts, not chooſing to enter raſhly into ſpeculations of ſuch ſubtlety, apply the term principle in general to all bodies, whether ſimple, or more or leſs compounded, which they obtain in their analyſes. Yet as principles, conſidered in this point of view, are very different from each other, they have divided them into proximate and remote principles. The firſt are ſuch as are ſeparated by a firſt analyſis, and may themſelves be compoſed of others; as for example, in decompoſing a vegetable ſubſtance, oils, mucilages, ſalts, and colouring matter, are ſeparated from each other, and are the proximate principles from which, by new operations, other principles may be had. By remote principles they mean ſubſtances more ſimple than the former, and which enter into their compoſition, ſince they may be obtained from them. Thus mucilage, which is a proximate principle of plants, affords by a new analyſis, oil, water, and earth, which are the remote principles of the plant. Other names have alſo been given to theſe two orders of principles, ſuch as principiated principles applied to thoſe before called proximate, and principiant principles to thoſe called remote. Theſe words imply, that the firſt are compoſed of other principles, and that the laſt are ſuch as ſerve to form or conſtitute others more compounded. Some chemiſts, for greater accuracy of diſtinction, admit ſeveral orders of principles. They call the moſt ſimple, or thoſe which cannot be farther decompoſed by the name of primitive, primary, or firſt principles. Principles compoſed of the moſt ſimple kind united are called ſecondary, or principles of the ſecond order. Principles of the third order or ternary, are compoſed of theſe laſt; and laſtly, thoſe into the formation of which principles of the third order enter, are termed quaternary, or principles of the fourth order, &c.

The number of elements has not been always the ſame among philoſophers. Some, with Thales the Mileſian, who was placed in the rank of the ſeven ſages of Greece, on account of his uncommon acquiſitions in knowledge, and who, according to Cicero, was the firſt of the Grecians who applied himſelf to natural philoſophy, have regarded water as the principle of all things. According to Anaximenes, air occupies this firſt place; and he did not ſcruple to deify this element, on account of its great importance. Some conferred this privilege on fire; others beſtowed the chief dignity upon the earth; the leader of whom was Anaximander, the diſciple of Thales, and maſter of Anaximenes. Every one found reaſons to ſupport his own opinion; but as the true method of conducting chemical and philoſophical inquiries was not then known, we can only eſteem theſe early notions as ſpeculations, void of all foundation. About three centuries after the time of theſe philoſophers, Empedocles, a phyſician of Agrigentum, thinking that the ſimplicity of the four ſubſtances contended for as the principle of all things to be equal, united their opinions, by admitting of four elements, fire, air, earth, and water. In the ſucceeding age, Ariſtotle and Zeno, adopted this opinion of Empedocles. When we reflect on the reaſons that may have engaged theſe philoſophers to regard fire, air, earth, and water, as elements, we are tempted to believe that it was not ſo much in conſequence of the accurate knowledge they could have acquired concerning theſe bodies, as in conſideration of the magnitude or quantity of them, and the conſtancy or invariability of their properties. Fire exiſts every where, and its effects are always the ſame. Our globe is ſurrounded by a maſs of air, the quantity and eſſential properties of which do not ſeem ſubject to variation. Water is preſented to obſervation on the ſurface of the globe, in an immenſe maſs, that fills up or conceals its abyſſes or cavities. And laſtly, the globe itſelf, whoſe volume far exceeds that of all the creatures that inhabit it, ſeems to be formed of a ſolid matter, little ſubject to change, capable of fixing or ſerving as a baſe for the other elements. It appears, therefore, that it was from conſiderations, founded on the bulk and apparent immutability of theſe bodies, that the early ſages were induced to regard them as the materials uſed by nature in the formation of all other beings.

The peripatetic doctrine which prevailed in the ſchools, preſerved the Ariſtotelian diſtinction of elements, till the ſixteenth century. At that period, the ſect of chemiſts, which began to prevail againſt the others, admitted a new diviſion of primary ſubſtances. Paracelſus, who was more of the artiſt than of the philoſopher, drew immediate inferences from the reſults of his operations, and acknowledged five principles; ſpirit, or mercury; phlegm, or water; ſalt; ſulphur, or oil; and earth. By ſpirit, or mercury, he underſtood every volatile and odorous ſubſtance, though ſimplicity is far from being a conſtant attendant on theſe properties. Water, or phlegm, comprehended in his ſyſtem, all the aqueous and inſipid products, and is liable to the ſame objection with reſpect to its pretended ſimplicity. The word ſulphur, or oil, denoted all inflammable and liquid ſubſtances, and conſequently a great number of bodies more or leſs compounded, as the fat and eſſential oils, &c. By ſalt, he indicated every dry ſubſtance poſſeſſing taſte and ſolubility, qualities that belong to a great number of compounds. Laſtly, the word earth was applied in the doctrine of Paracelſus, to the dry, fixed, and inſipid reſidues of operations, all of which are now known to differ exceedingly from each other.

Beccher, a chemiſt, who has treated his ſubject in the moſt philoſophical manner, was aware of the objections that might be urged againſt the doctrine of Paracelſus, and from a conviction of its inſufficiency, he took another method of arriving at the elements of bodies. He firſt diſtinguiſhed two principles very different from each other, humidity and dryneſs, water and earth. He divided this laſt into three ſpecies; namely, the vitrifiable, inflammable, and mercurial. Vitrifiable earth, according to him, was that which alone poſſeſſed the greateſt immutability; but when mixed with ſome ſaline earth, was capable of forming the moſt perfect glaſs. He likewiſe attributed to it the property of rendering the combinations into which it entered ſolid, and little ſubject to change. The inflammable earth was known by the combuſtibility of the combinations it enters into. Beccher regarded it as the cauſe of ſmell, colour and volatility. The mercurial earth he ſuppoſed to conſiſt in mercury, arſenic, marine acid, &c. &c.; and its peculiar character was that of giving a very conſiderable volatility and ſpecific gravity to the compounds in which it exiſted, two inconſiſtent and oppoſite qualities. Stahl adopted, and commented on the doctrine of Beccher. He regarded the inflammable earth as fire fixed in bodies, and gave it the name of phlogiſton. He could not ſucceed in demonſtrating the exiſtence of mercurial earth, and there has nothing been done to this day, which at all eſtabliſhes it. Stahl paid the greateſt attention to combinations containing earth, water, and eſpecially phlogiſton; but he has ſaid nothing concerning air, which Hales, nearly at the ſame period, proved to be a principal agent in chemical phenomena.

From the time of Beccher and Stahl to the preſent, no change has been made by chemiſts in the doctrine of the elements laid down by the ancient philoſophers. Like Empedocles, they have acknowledged four elements, and have conſidered each in two different ſtates. 1. As free, or inſulated; in the large maſſes of air in the atmoſphere, fire taken in general, water, and the earth attended to at large. 2. Or as combined; and in this ſtate they conſider the air, water, and earth obtained from different bodies in their ultimate analyſis.

Such were nearly the opinions adopted reſpecting the principles of bodies, from the time of Beccher and Stahl, till the valuable diſcoveries of Prieſtley and Lavoiſier, on fixed air and combination, neceſſarily introduced new opinions. In fact, if immutability of properties, unity, and ſimplicity, be the true characters of elements; and if it be admitted that this ſimplicity no longer exiſts, when a body is found to be capable of decompoſition, it muſt be remarked: 1. That among the four elements there are at preſent two, namely air and water, the principles of which, art has ſucceeded in decompoſing and ſeparating. 2. That elementary earth is a creature of the imagination; ſince it can be ſhown, that there are many earthy ſubſtances equally ſimple and incapable of decompoſition, as will be done in the concluding chapter of this firſt part.

From this general enumeration of facts hereafter to be more fully explained, it follows, that the true principles or firſt elements of natural ſubſtances eſcape our ſenſes and our inſtruments; that many of thoſe which have been called elements, on account of their volume, their influence in the phenomena of nature, and their multiplied exiſtence in its different products, are very far from being ſimple and unchangeable bodies; and that probably there is no body which falls under our ſenſes which is ſimple, but only appears ſuch to us, becauſe we do not poſſeſs the means of decompoſing it. Theſe aſſertions moreover agree with the opinions of ſome of the ancient philoſophers, who did not regard the elements as the moſt ſimple bodies, but ſuppoſed them to be formed of principles of a far greater degree of tenuity and unchangeableneſs.

Theſe notions concerning thoſe bodies, which have for ſo many ages enjoyed the excluſive title of elements, and to which we deny that prerogative, do not prevent us from conſidering fire, air, earth, and water, as containing the principles of which moſt other natural bodies are formed.

We will finiſh this detail, by explaining a kind of nomenclature adopted by certain methodical writers, in diſtinguiſhing bodies, according to the order of the principles that enter into their compoſition.

If two elements or principles are united or combined together, there reſults a body called a mixt. A number of mixts form a compound. Two compounds united form a ſurcompound. The combination of ſurcompounds produces a decompound, and theſe laſt, in like manner, generate ſurdecompounds. It is not eaſy to give examples of theſe different kinds of compoſition, as we can ſcarcely proceed ſo far as ſurcompounds. Theſe diſtinctions appear, therefore, to be ideal, and of no uſe. M. Macquer, to whom chemiſtry is indebted for much of its perſpicuity, propoſes to change this barbarous and inaccurate nomenclature, and inſtead of it to ſubſtitute the words compound of the firſt, ſecond, third, &c. order. Or we may adopt the ſame terms to diſtinguiſh chemical principles in the order of analyſis by which they are obtained, inſtead of the order of their compoſition.

CHAPTER V.

CONCERNING FIRE.

THOUGH we neither admit of the word element in the ſenſe uſually applied to it, nor entertain the opinion that the four bodies, ſo called, are the immediate principles of all others, or the moſt ſimple in nature; yet we think it neceſſary to attend to them in the firſt place, becauſe the hiſtory of their properties will be uſeful in the explanation of thoſe of the other bodies, of which we ſhall hereafter treat; and in the next, becauſe they cannot be ranged in any order relative to natural hiſtory, becauſe they are common to all the kingdoms of nature.

Among the four bodies called elements, no one appears to be more active, nor at the ſame time more ſimple, than fire. The moſt ancient philoſophers, and after them philoſophers in every age, have given this name to a ſubſtance which they ſuppoſed to be a fluid extremely moveable and penetrating, formed of particles continually agitated, by them regarded as the principle of fluidity and of motion. When we reflect on this ſubject, we ſhall find that theſe properties could only be attributed by conjecture to a body placed among the elements, ſince its exiſtence has never been demonſtrated; as that of the three other elementary ſubſtances has always been. It is, indeed, natural to think that this name, fire, has in all languages and times, been given to the impreſſion that heated bodies communicate, or make on the ſenſes: And which is ſynonymus to the term heat, as well as to the light that bodies emit when in combuſtion. This is the idea which the greater part of mankind entertains; they recognize the preſence of fire only by that of heat and combuſtion. The Chancellor Bacon is one of the firſt who doubted the exiſtence of fire as a peculiar fluid, and took notice that philoſophers, in defining it, had always miſtaken a property for a ſeparate ſubſtance. Boerhaave, whoſe treatiſe on Fire will always be regarded as a maſter-piece, was ſenſible of this difficulty, and in order to render the properties of this pretended element more evident, he examined its effects on bodies wherein it is thought to exiſt; ſo that he, like all the philoſophers who preceded him, has written a hiſtory of heated, luminous, rarified, burning bodies, rather than that of fire itſelf. This confuſion is likely to be always found in natural philoſophy; for the properties of fire are neceſſarily connected with thoſe of the bodies whereon it acts; ſo far from having it in our power to inſulate it, we cannot even form an idea of its ſeparate exiſtence: And notwithſtanding the advanced ſtate of chemiſtry, it has not been found poſſible to ſeize and confine this principle, which philoſophers ſeem agreed to call a fluid, and whoſe effects they explain with ſufficient facility, when, led by cuſtom, they regard its exiſtence as well eſtabliſhed. Theſe difficulties have cauſed ſeveral chemiſts, and in particular Macquer, to believe, that fire is nothing elſe but light, and that heat is a modification of bodies ariſing from the motion and colliſion of their particles. This opinion no longer exiſts among philoſophers who cultivate the ſcience of chemiſtry. To form an adequate notion of the different theories propoſed for ſome years paſt, reſpecting fire, we muſt not confine our attention to general poſitions. The ideas we ſhould deliver, would be as vague as the ſubject itſelf. The only method of attaining exactneſs, and to throw light on the immenſe number of facts that compoſe the ſcience of chemiſtry, is to divide the ſubject, and examine its parts ſeparately. We ſhall conſider in ſucceſſion as ſo many particular effects of fire, light, heat, rarefaction, the changes produced in bodies by heat, and thoſe which are attributed to combined fire, formerly called phlogiſton [a].

§ 1. *Concerning Light.*

We cannot entertain the ſame doubt concerning the exiſtence of light, as of fire, becauſe its exiſtence and properties are at preſent well known and eſtabliſhed. This ſubſtance, which is thought to be emitted from the ſun and fixed ſtars, is the cauſe in moſt caſes of our perception of other bodies. This matter, reflected in right lines from the ſurface of bodies, is the cauſe of the ſenſation of ſight, by producing an image of external objects on the retina of the eye. By the aſſiſtance of a darkened chamber, means have been found to examine its peculiar properties ſeparate and diſtinct from thoſe of the bodies from which it is emitted.

The extreme velocity of light is ſuch, that it paſſes through the ſpace of 80,000 leagues * in a ſecond, according to the moſt eminent aſtronomers. Its motion is rectilinear, it conſiſts of rays, which after iſſuing from luminous bodies, ſeparate and continue to diverge in proportion as they obey the motion, which had been communicated to them. The elaſticity of the rays, or the reaction of the power that reflects them is ſo perfect, that the angle of their reflection does not ſenſibly differ from that of their incidence, as is ſhown by writers on catoptrics. When light paſſes near any ſubſtance whatever, it is more or leſs inflected, and this inflection, proving that it is ſubject to gravitation as a body itſelf, is an evidence of its exiſtence.

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* Of 25 to the degree, or 167,000 geographical miles. T.

Notwithſtanding the velocity of light, it is eaſily deflected out of its courſe, as well by the bodies it paſſes through, as by thoſe it paſſes near. When its courſe is oblique from a rare medium into a denſer, it is refracted, or ſuffers a change in its direction like other ſolid bodies; but Newton * diſcovered that its refrangibility is in the inverſe ratio of that of all other bodies; for other bodies in paſſing into denſer media, recede from the perpendicular; but light, in theſe circumſtances, approaches nearer to it. For a more minute detail of the properties of light, reference muſt be made to books written expreſsly on the ſubject of optics.

Light, when it arrives at the ſurface of the earth, announces to animals the preſence of the bodies which ſurround them, and enables them to diſtinguiſh theſe bodies into opaque, tranſparent, and coloured. Theſe three properties are ſo eſſentially connected with the preſence of light, that bodies loſe them in the dark, and become undiſtinguiſhable. The difference in the opacity, tranſparency, and colour of bodies, depends, therefore, on the manner in which they affect, or are affected by light.

Tranſparency is the property of admitting the rays of light to paſs eaſily through any ſubſtance, and doubtleſs ariſes from the form of the pores †. As this property is found in the heavieſt and hardeſt bodies, it muſt follow as a conſequence, that the tenuity of light is extreme. When thus tranſmitted, the refractions it undergoes are in proportion to the denſities, when the bodies are either ſtones, ſalts, or glaſſes, but is greater when the bodies are of the claſs of combuſtibles. Thus yellow amber has a greater refracting power, than a ſaline cryſtal of equal denſity.

It was by an examination of the refractions and reflections of light, that Newton ſucceeded in decompoſing, or rather diſſecting

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* Newton did not diſcover this. Des Cartes firſt publiſhed the diſcovery of the conſtant ratio of the ſeries of incidence and refraction; though it was certainly known before to Willebrord Snellius; and Kepler was very near diſcovering it. T.

† The minuteneſs of the particles, and ſmallneſs of the pores. See Newt. Opt. T.

this body, and in proving that the different rays, which compoſe a beam of light, are each capable of exciting the idea of a different colour. Before his time, very little was known reſpecting the cauſe of colour. As each kind of ray is differently refrangible as well as reflexible, it is found that a beam of light received on a priſm of glaſs is ſeparated into its various component rays by refraction as it paſſes through, and being intercepted at ſome diſtance by a white plane, or body equally capable of reflecting all, they form a long ſpectrum, conſiſting of the colours in the following order, namely, red, orange, yellow, green, blue, indigo, and violet; the red being compoſed of ſuch rays that have been the leaſt refracted out of their courſe, and the others being more and more refrangible in their order.

The particles at the ſurfaces of opaque bodies appear to produce an effect on light reſembling that of the priſm *. It is on this property of the particles, that all the variety of colours, which charm the ſight, depends. The fact is, that bodies are white, when they reflect or return back all the rays of light that fall on them; and, on the contrary, when all the rays are abſorbed, we perceive a defect of light, which we call black, and is in reality the abſence of all colour: And again, every beam of white light being compoſed of a ſeries of the ſeven primary colours, and of every poſſible intermediate tinge, all differing in reflexibility, each particular body will appear of the colour it is conſtructed to reflect, while it abſorbs the greater part of the rays of every other colour. Colour, therefore, depends on the nature of the ſurface of the bodies, as tranſparency does on their pores, and both are produced by the modifications which the light experiences at the ſurface, or in the interior part of the bodies on which it falls. Thus, for example, the colour called blue, or red, is produced in bodies by an abſorption of all the other rays, except the blue or red, which are reflected back.

Theſe are the chief properties of light conſidered as emitted from the ſun or the fixed ſtars. But ought we to confine our inquiries reſpecting this ſubſtance to its free and inſulated ſtate. Does it not, like every other body we are acquainted with, obey the laws of affinity in the ſame manner as it is found to be ſub-

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* The ſepartion of light into coloured rays, in conſequence of its falling on tranſparent particles of definite magnitude (and all minute bodies are tranſparent), has not yet been ſhown to be of the ſame kind, or performed in the ſame manner, as the ſeparation effected by the priſm. T.

ject to attraction? This conjecture is rendered more probable, by the conſideration that the effects of light do not ſeem to be confined to its mere re-action on bodies that modify or alter its courſe. If it be true, that bodies expoſed to the contact or impulſe of light, experience an alteration or change of nature without any other evident cauſe, it muſt follow, that light itſelf is the agent, and produces its effects by a chemical attraction. Though it has not yet been poſitively decided, whether their changes ariſe from the decompoſition of light itſelf, or of the bodies thus altered, or of both together, which is extremely probable; the facts are too numerous and too ſtriking to be overlooked. We ſhall content ourſelves with mentioning in this place only ſuch as are of the moſt conſequence, and the beſt eſtabliſhed; as it is our intention to treat the ſubject more fully in our hiſtory of each natural body in its order.

Natural philoſophers have long been aware of the influence of light on vegetation. It was firſt obſerved, that plants growing in the ſhade are pale, and without colour. The term *etiolation*, has been given to this phenomenon, and the plants are ſaid to be *etiolated*, in which it takes place [b]. Herbs that grow beneath ſtones are white, ſoft, aqueous, and of a mild or inſipid taſte; and gardeners avail themſelves of the knowledge of this fact, to furniſh our tables with white and tender vegetables, by binding up and compreſſing their leaves together, ſo as to defend them from the contact of light. The more plants are expoſed to the ſolar rays, the more colour they acquire. Such, therefore, is the origin of thoſe colouring matters, of ſo much value for their livelineſs and body, which many of the eaſtern nations extract from woods, bark, and roots, &c., and which the utmoſt induſtry of the European dyers has not ſucceeded in imitating.

Colour is not the only property that is obtained by vegetables from the contact of the rays of light. Taſte, odour, and combuſtibility, are likewiſe derived from the ſame ſource. Light contributes greatly to the maturity of fruits and ſeeds; and is the cauſe why, under the burning ſun of America, vegetables are in general more odoriferous, of a ſtronger taſte, and more abounding with reſin. From the ſame cauſe it happens, that hot climates ſeem to be the native country of perfumes, ſtrong ſmelling fruits, dying woods, and reſins of various kinds. Laſtly, the action of light is ſo powerful on the organiſm of vegetables, as to cauſe them to pour forth torrents of vital, or pure air, from the ſuperior ſurface of their leaves into the atmoſphere, while expoſed to the ſun-ſhine; whereas, on the contrary, when in the ſhade they exhale nothing but a noxious fluid, or true acid, ſimilar to that obtained from chalk. This important diſcovery due to Dr. Prieſtley, and more minutely inquired into by M. Ingenhouſze, ſhows, in a ſtriking manner, the influence of light on vegetation. The effects of light are equally ſeen in a great number of chemical operations. There is not a ſubſtance, which in well cloſed glaſs veſſels, and expoſed to the ſun's light, does not experience ſome alteration from this cauſe. Among theſe, the mineral acids, the metallic oxyds or calces, vegetable powders, and volatile animal oils, are moſt ſingularly changed. Metallic oxyds in general, eſpecially thoſe of mercury, become of a deeper colour, by expoſure to the ſun; as may be ſeen by obſerving painters colours preſerved in powder in the ſhops *. The mineral acids, by the ſame treatment, become higher coloured, more volatile and fuming. Metallic ſalts grow black, and animal oils take an obſcure brown. All theſe changes deſerve the greateſt attention of chemiſts, and they form an immenſe ſeries of reſearches which has not yet been ſufficiently inveſtigated. Scheele is the firſt chemiſt who has deſcribed ſome of them; M. Berthollet has likewiſe attended to this ſubject, and we ſhall hereafter ſee that he has determined what happens in many of theſe alterations.

§ 2. *Concerning heat* †.

The difficulties that attend the inquiry concerning heat are much more numerous than thoſe relating to light. It cannot be

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* It has been remarked, however, that the parts of a room painted with white lead and oil, which are defended from the light by furniture, or by keeping the windows cloſed, become of a darker colour than the reſt; and that the action of light permitted to fall on ſuch obſcure parts of the ſurface, in ſome meaſure reſtores the original colour or whiteneſs. T.

† The importance of the theory of heat in chemical inquiries has induced the tranſlator to give a more ſtrict and leſs diſcurſive view of the ſubject than is exhibited in the text.

1. Temperature is the ſtate by which a body poſſeſſes the power of exciting the undefinable ſenſations of heat or coldneſs.

2. The word heat is uſed as a term to denote the cauſe of that ſtate.

It is to be obſerved, that the words temperature and heat are here taken in the moſt extended ſenſe. The organs of the human frame are not only imperfect when applied to meaſure the temperatures of bodies, but likewiſe exceedingly liproved by weight that heat is a ſelf-exiſtent, a ſeparate ſubſtance; and many eminent philoſophers have embraced the opinion of Bacon, that it is nothing more than a modification, of which bodies

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mited in this as well as in every other caſe. Temperature is therefore uſed to denote every degree of heat or coldneſs, whether within the limits of perception or not, and is appreciated by the obſervation of its effects on bodies.

Heat, conſidered as the cauſe of temperature and of other effects, is ſubject to variation. It is therefore an object of mathematical inquiry, as poſſeſſing quantity either abſolutely, or in the ſame ſenſe as various attributes, ſuch as ratios or motion, are ſaid to poſſeſs it. But it is no part of this inquiry, whether heat be motion or matter. Perſpicuity requires that theſe objects ſhould be ſeparately attended to.

3. Bodies in contact, or communicating with each other, do, after a length of time, aſſume or acquire one common temperature.

4. The time of acquiring the common temperature is different in different bodies. A body, which quickly alters its temperature by communication, is ſaid to be a better conductor of heat than ſuch as alter more ſlowly.

5. When the temperature of a given ſolid is increaſed, there is a certain period at which it becomes fluid; and as the temperature is increaſed beyond this laſt point, the fluid takes a rare and elaſtic form, with more or leſs rapidity forming vapour. Whether an increaſe of temperature would convert vapour into a fourth ſtate, namely, that of a permanently elaſtic fluid, or air, has not been decided; but it is probable.

The temperatures at which different bodies aſſume the fluid or vaporous ſtates are exceedingly various. Some bodies, as for example, mercury, are not frozen but by extreme cold: others, as rock cryſtal, cannot be melted, but by the moſt vehement heat modern chemiſtry can excite: others again cannot be brought into ſome of the ſtates; and of theſe the rule is inferred from analogy, till future experiments may tend to clear up the matter.

6. Univerſally the effects of an increaſed temperature are either (1) converſion of the whole body into fluid or vapour; or (2) decompoſition, by one or more of the chemical principles of the body being melted or volatilized; or (3) without change of ſtate or compoſition, an increaſe of the dimenſions, which laſts no longer than while the increaſed temperature remains.

7. Axiom 1. The quantities of heat in two equal bodies of the ſame kind and temperature are equal.

8. Theorem 1. The quantities of heat in bodies of the ſame kind and temperature are as their maſſes.

9. Theorem 2. Two equal bodies of the ſame kind, but different temperatures, being brought into contact; the hotter will impart half its ſurplus of heat to the other.

For (by 3) they will acquire a common temperature by contact, and by that means (7), the quantities of heat will be made equal. This can only be effected by the hotter body imparting half its ſurplus.

10. Theorem 3. Two bodies of the ſame kind, but different temperatures, being brought into contact; the ſurplus of heat, by means of which the one exceeded the other in temperature, will be divided between the two bodies in proportion to their maſſes.

For (3) They will acquire a common temperature, and the whole quantity of heat in each will then (8) be in proportion to its maſs. This can only be effected by dividing the ſurplus in the ſame proportion.

11. Corollary 1. The quantities of heat required to be added to, or taken from

are ſuſceptible. It is certain that philoſophers, as well as the common rank of men, have always ſuppoſed heat to indicate the preſence of fire, and have ſometimes taken it for the element itſelf, and on other occaſions for one of its characters.

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bodies of the ſame kind, to bring their temperature to a given ſtandard, will be as their maſſes.

12. Corollary 2. Hence a thermometer, with a very ſmall bulb, may be conſidered as poſſeſſing the temperature of the body it is in contact with, becauſe the common temperature will not ſenſibly differ therefrom when the body is of conſiderable magnitude.

13. The mercurial thermometer nearly meaſures the true increments of temperature.

This is determined by experiment (by De Luc). Let a thermometer be graduated ſo as to ſhow the equal increments (6) of the expanſion of the mercury; and the common temperature of two equal bodies of the ſame kind in contact (as for example, meaſures of water) will be nearly the arithmetic mean between the two original temperatures, as ſhown by ſuch an inſtrument. The inſtrument therefore gives reſults nearly agreeing with deductions (9) made from the general phenomena of heat, or it nearly meaſures the true increments of temperature.

14. Axiom 2. If two equal maſſes at different temperatures be brought into contact, and the common temperature be either higher or lower than the arithmetical mean (9), the ſurplus of heat, by means whereof the one exceeded the other in temperature, will be unequally divided; and the diſpoſition to be heated, or the capacity or affinity for heat, is greater in one body than in the other.

15. Theorem 4. The capacity of equal maſſes for heat are inverſely, as the changes of temperature they undergo, when differently heated and brought into contact. And the contrary.

For the ſurplus of heat is divided into equal parts by the thermometer: of theſe parts, the hotter body loſes a certain number by communication to the colder, and retains the remainder. The number of degrees loſt, conſtitutes the change of temperature in the hotter, and the remainder is the change in the colder. But cauſes are ever proportional to their effects: therefore the capacities are as the proportions of heat retained by each, that is, inverſely as the changes of temperature.

16. Corollary 1. Hence if any given body, as for example, fluid water, be aſſumed as a ſtandard, the capacities of other bodies being experimentally found, may be ranged numerically, ſo as to form an uſeful table.

17. Corollary 2. The quantities of heat required to be added to or taken from bodies of equal maſs, to bring their temperature to a given ſtandard, will be as their capacities.

18. Corollary 3. The quantities of heat required to be added to or taken from bodies in general, to bring their temperature to a given ſtandard, will be as their maſſes (11), and their capacities jointly.

19. Corollary 4. The capacities, in general, will be directly as the quantities of heat ſo taken, and inverſely as the maſſes; or they will be in the inverſe ratio of the changes of temperature, and the maſſes of two bodies placed in contact. This, in the form of a practical rule, is, multiply the weight of each body by the number of degrees between its original and the common temperature, and the capacities of the bodies for heat will be inverſely as the products.

Its leading properties are, to penetrate all bodies; to diffuſe itſelf uniformly[d], ſo as to tend to an equilibrium; to dilate the ſeveral ſubſtances it penetrates; and, laſtly, to cauſe them to aſſume the ſtate of fluidity, and afterwards that of vapour.

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20. Theorem 5. The whole quantities of heat contained in the bodies of equal maſs and temperature are as their capacities.

For if the the temperatures of various bodies be ſuppoſed gradually and equally to diminiſh till the abſolute privation of heat be obtained, the quantity of heat given out in any portion of the time (17) will be proportional in each body to its capacity. And the whole time being made up of ſuch portions, the reſpective ſums of the quantities of heat given out by each body will be in the ſame ratio.

It is the buſineſs of experiment to determine whether the ratios of the capacities be the ſame in all temperatures, cæteris manentibus.

21. Scholium. From the foregoing theorem, many writers have called a table of capacities by the name of a table of ſpecific heats. Theſe terms, which ſeem improper, or at leaſt unhappy, becauſe applied to quantities that continually fluctuate, have certainly rendered the theory of heat leſs eaſy to beginners.

22. As far as experiments have hitherto been made, it is found that the capacity of a given body for heat is leaſt when ſolid, greater in the fluid ſtate, and greateſt in the vaporous ſtate.

Thus for example, ice and water being expoſed in equal quantities to ſimilar heating matters, as before a fire, the ice will be melted without increaſe of temperature, while the water acquires 162° of Fahrenheit's thermometer. Or equal parts of water at 162, and ice at 32° being mixed, the ice will melt, and the whole, inſtead of the mean temperature, will remain at 32°. In either caſe the ice requires 130° of heat, which produces no other effect than rendering it fluid, and is not ſhown by the thermometer. So likewiſe the condenſation of ſteam, though little if at all hoter than boiling water, communicates much more heat to a refrigeratory, than the ſame quantity of water equally hot, and therefore it contained more heat. The quantity of heat which conſtitutes the difference between the ſeveral ſtates of the body, has been improperly called latent heat.

23. Problem. The ratio of the capacities of the ſame body in the ſolid, and the fluid ſtates, and alſo the number of degrees the fluid would increaſe in temperature by the heat which would ſimply melt the ſolid, being given; it is required to determine the number of degrees of the ſame thermometer, between the natural zero, or abſolute privation of heat, and the temperature of the ſolid juſt melting.

The whole quantity of heat in the ſolid, when juſt melting, will be denoted by the number of degrees of its temperature from the natural zero: and the whole quantity of heat in the fluid will be denoted by the ſame number added to the number of degrees the temperature of the ſolid would have been raiſed by the heat applied to melt it, if its capacity had not been changed by melting. This laſt number conſiſts of the obſerved increaſe of temperature in the fluid augmented in the inverſe ratio of the capacities (15). Now the capacities of the ſolid and fluid being as their whole quantities of heat (20), it will follow that

The difference between the numbers expreſſing the capacities,
Is to the number expreſſing the capacity of the ſolid;
As the difference between their reſpective quantities of heat in thermometrical degrees of the ſolid;

Bodies become heated, in general, in three manners, either by the contact of another heated ſubſtance, or by motion, or by the act of combination. Every one muſt have obſerved, that in mixing two ſimilar fluids, the one ſenſibly hot, and the other cold, the former loſes part of its heat by communication to the ſecond, and the temperature becomes equal in each; and the ſame is true

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Is to the number of degrees expreſſing its whole quantity of heat, or its temperature from the natural zero.

This in the form of a practical rule, is, multiply the number expreſſing the capacity of the fluid into the number of degrees the fluid would have increaſed in temperature by heat, ſufficient to melt the ſolid; divide this product by the difference between the numbers expreſſing the capacities, the quotient will be the number of degrees of temperature from the natural zero.

This problem is Dr. Irwine's, of Glaſgow.

From experiment, it appears, that the natural zero is 1268° of Fahrenheit's ſcale below 0, or 1300 degrees below the freezing point of water.

24. Corollary. The difference between the zero of any ſcale, and the natural zero, being once determined from experiment, it will be eaſy in all caſes, where any two of the three quantities, the capacity of the fluid, the capacity of the ſolid, and the number of degrees the fluid would be raiſed by heat ſufficient to melt the ſolid, are given to find the third.

25. The foregoing theory of heat may be applied to explain all the changes of temperature in bodies, from the utmoſt violence of ignition to the moſt intenſe cold. For whenever by condenſation or freezing, or by a change in the chemical combinations of bodies, the capacities are diminiſhed, a part of the heat contained will (15) be applied in raiſing the temperature. And, on the contrary, cold will be produced whenever bodies are melted, or evaporated, or any chemical proceſs goes forward, by which the capacities are increaſed.

26. The grand queſtion, whether heat be merely a vibration of the parts of bodies, or a peculiar fluid, is not decided. If heat be merely vibration, it will be ſcarcely poſſible to account for its not being univerſally communicated to bodies according to their maſſes, as the eſtabliſhed laws of motion require; but if heat be a peculiar fluid, the notion of a greater or leſs capacity for that fluid, whoſe variations of denſity will be the cauſe of change of temperature, will very naturally account for the different quantities required to be imbibed or given out by bodies of equal weight, before a like denſity or temperature can be produced in all. Neither will it be at all difficult, according to this hypotheſis, to give very probable accounts of what happens when bodies change their ſtates of ſolidity, fluidity, or vapour.

27. The various theories reſpecting heat, conſidered as matter, and a component part of bodies, are not ſufficiently grounded on deciſive facts, to admit of a curſory diſcuſſion in this place, or indeed to be ranked with the eſtabliſhed doctrines collected and arranged in this preſent note, though it muſt be allowed that ſeveral of them do honour to the genius and abilities of their inventors. Dr. Black of Edinburgh, Profeſſor Wilcke of Stockholm, Dr. Irwine of Glaſgow, Dr. Crawford of London, are among the leading names of philoſophers who invented and illuſtrated this excellent theory here explained; and it is ſincerely to be wiſhed, that ſome cotemporary writer would ſettle their reſpective claims before the lapſe of time ſhall have rendered it difficult. T.

of ſolid bodies that have remained a ſufficient time in contact. The developement of heat, by means of motion, is equally well known. Two hard ſtones, or pieces of wood or ivory, or metallic matters, ſtrongly rubbed or ſtruck together, produce a degree of heat, that in many caſes proceeds even to ignition[e]. And the production of heat by the act of combination is evidently ſeen in the union of concentrated acids with water, quick-lime, pure alkalis, metals: And inflammation follows on the mixture of certain fluids, as the nitrous acid and oils.

The laws of the communication of heat between bodies were thought to be analogous to thoſe of motion, till the labours of Meſſrs. Black of Edinburgh, Wilcke of Stockholm, Irwine of Glaſgow, Crawford of London, and Lavoiſier of Paris, ſhowed that nothing is leſs known, or more difficult to be known, than the progreſſion and communication of heat in the ſyſtems of bodies of unequal temperature. The very ingenious experiments of theſe philoſophers are not yet ſufficiently numerous, and they themſelves depend too little on their general reſults, to admit of their being regarded as part of the elements of chemical ſcience. It is, however, very probable that they will lead the way to the eſtabliſhment of a general theory of heat, applicable to all the phenomena of chemiſtry, in every one of which it is concerned, either as being abſorbed or diſengaged[f].

The moſt accurate experiments have not yet produced any deciſive principles reſpecting the nature of heat; and chemiſts, as well as the philoſophers in other branches of natural ſcience, are divided in their opinions concerning it. Some, with Lord Chancellor Bacon, think that heat is nothing elſe but a modification of which all bodies are ſuſceptible, not exiſting independent of bodies, but conſiſting merely in the oſcillation of their particles. Such was the opinion of the late Mr. Macquer. This ſet of philoſophers ground their opinion on the following facts: Heat follows motion in all its phenomena, and appears to obey the ſame laws; it conſtantly accompanies motion, increaſing and diminiſhing in the ſame proportion. If we except the differences it preſents in its communication or paſſage from one body to another, which do not appear reconcileable with that of motion, the analogy between both is ſtriking in all its other properties. When the cauſe which produces it abates or ceaſes entirely, the heat is diminiſhed, and ſoon diſſipated. That this hypotheſis may be the more readily admitted, it is obſerved, that bodies even of the greateſt denſity, have a great number of cavities or pores, whoſe dimenſions may exceed that of the real matter of which the body in queſtion is compoſed. Theſe void ſpaces permit the particles to move with reſpect to each other, and to oſcillate in every direction. Theſe oſcillations eſcape our ſenſes, for the ſame reaſon as the parts and powers themſelves do, namely, their minuteneſs. And, laſtly, theſe philoſophers who conſider heat as an inteſtine motion, take notice that the contrary opinion of heat, being matter, has never been proved by any poſitive experiment, either from its being ſhown to have gravity, or from the other properties aſcribed to it.

Many other philoſophers, and ſome modern chemiſts, on the contrary, believe that heat is a peculiar fluid, exiſting in bodies, all which it penetrates with greater or leſs facility. They diſtinguiſh this fluid in two ſtates, in combination, or at liberty: The former is not ſenſible to our organs, nor indicated by the thermometer. It is in a ſtate of repoſe in bodies, conſtituting one of their principles. It exiſts in them in a ſtate of greater or leſs compreſſion. It is often diſengaged in decompoſitions, and then paſſes to the ſtate of heat at liberty; it becomes capable of acting on the bodies expoſed to its influence; and its intenſity and variations may be aſcertained by the thermometer *. As all bodies that paſs from the ſolid to the fluid ſtate, and from this laſt into the ſtate of vapour, produce cold in the ſurrounding bo-

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* There are two opinions concerning the change of temperature which bodies undergo when they change their ſtate or their mode of combination: By ſuch changes it is found that heat is either abſorbed or given out; or to ſpeak more unexceptionably, the alterations of temperature are either leſs or greater than would have been inferred from general reaſoning. Some philoſophers ſay, that the capacities of the bodies are changed, and therefore require more or leſs heat to occaſion ſimilar mutations of temperature than they did before (ſee our note on p. 146) others affirm, that the heat which diſappears or appears has no relation to the capacity, but is either received in combination, as a principle of bodies, or given out as ſuch. Theſe poſitions are not matter of opinion, but relate to facts, about which philoſophers will acquire more knowledge by experiment than by reaſoning. If the natural zero be determined truly by Dr. Irwine's theorem, (note on p. 146) and the capacities of various bodies in their ſtates of ſolidity and fluidity, be found from direct experiment, the corollary to that theorem will give the number of degrees the fluid would be raiſed by heat that would ſimply melt the ſolid. If this deduction ſhould be found in all caſes to agree with the facts, the former opinion is true; but if not, there is a portion of heat not accounted for, which, if heat be matter, may probably be a principle of bodies. Fiant Experimenta. T.

dies, they ſuſpect that there is a great quantity of the matter of heat abſorbed by theſe bodies; and that when, on the contrary, fluid ſubſtances become concrete, and produce heat, this laſt is diſengaged from the ſubſtance that contained it, and has paſſed from a ſtate of combination to a ſtate of liberty.

Mr. Scheele, who, as well as Mr. Bergman, is perſuaded that heat is a ſelf-exiſtent body, has, with great care, examined the phenomena it preſents as a chemical agent, capable of entering into combinations. He has even thought himſelf juſtifiable in concluding, from his experiments, that it is compoſed of vital air, which he calls empyreal air, and fixed fire or phlogiſton; and that it differs from light only in the relative quantity of this latter principle. But however ingenious and true the reſults of the experimental inquiry he has entered into may be, his inductions concerning the nature and principles of heat, do not ſeem, in our opinion, to follow naturally, nor prevent our continuing to think that the analyſis of heat is not yet accompliſhed. Some philoſophers think that light and heat are the ſame ſubſtance, and differ only in their ſtate. This body is light, when its particles, collected together, and poſſeſſing all their attraction, are projected with great force; it is heat when the ſame particles, in a ſtate of diviſion, move ſlowly, and tend to an equilibrium. They think that heat can become light, and light heat:—it cannot, however, be denied that light often produces effects very different from heat; as takes place in the nitric acid, the oxygenated muriatic acid, the metallic calces or oxydes, and the leaves of vegetables plunged in water: All theſe bodies give out vital air, or oxygenous gas, when they are expoſed to the rays of the ſun, and moſt of them do not afford it by the action of heat alone. It is in this manner that the artificial light of our fires, paſſing through the veſſels, changes the nature of the products which are diſengaged.

Laſtly, Meſſrs. Lavoiſier and De la Place ſeem to ſuſpect that both hypotheſes are true, and take place at the ſame time, that is to ſay, that heat conſiſts in the exiſtence of a peculiar fluid, and in the inteſtine oſcillations of the parts of bodies excited by its preſence.

Whatever may be the nature of heat, the phenomena it preſents in chemical combinations and decompoſitions, are not the leſs certain, nor the leſs deſerving our moſt careful attention. A great number of facts have eſtabliſhed it as a certainty, that this body or modification is unalterable in itſelf, and is not deſtroyed or loſt. And theſe have induced Meſſrs, Lavoiſier and De la Place to give the following important principle as an axiom reſpecting the appearance or diſappearance of heat. As this principle is of the greateſt importance to the theory of chemiſtry, we ſhall inſert it here.

"If in any combination or change of ſtate whatſoever, there " be a diminution of free heat, this heat will appear again undi" miniſhed when the ſubſtances return to their firſt ſtate; and " reciprocally, if in any combination or change of ſtate there be " an augmentation of free heat, this new heat will diſappear " during the return of the ſubſtances to their original ſtate."

In rendering this principle more general, and extending it to all the phenomena of heat, they have uſed the following mode of expreſſion: "All variations of heat, whether real or apparent, " which are experienced by a ſyſtem of bodies, in changing their " ſtate, will be re-produced in an inverſe order, when the ſyſtem " paſſes again to its firſt ſtate."

To meaſure the quantity of heat abſorbed or diſengaged in the different chemical phenomena, being an operation which, after what has been ſaid, muſt evidently appear to be of the higheſt importance, philoſophers have endeavoured to avail themſelves of means, by which the defects of thermometers might be ſupplied. Their ſcales not being ſufficiently extenſive, nor the information they afford, ſo accurate as was at firſt believed, Mr. Wilcke propoſed to eſtimate the quantity of heat from the quantity of ſnow to be melted by the bodies under examination; and Meſſrs. Lavoiſier and De la Place have contrived a certain and eaſy method of carrying this propoſal into practice *. It conſiſts in placing bodies which produce heat by their combination (after reducing them, as well as the veſſel containing them, to the temparature of 32° of Fahrenheit), in a veſſel ſurrounded with ice, the interior layer only of which can be melted by the heat

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* From ſome attempts made by the ingenious Mr. Wedgwood, to avail himſelf of this inſtrument, it ſeems that the capillary attraction of the pounded ice, retaining a portion of the water that ſhould flow out, and ſome unexplained circumſtances, where the vapour raiſed by bodies, at very high temperatures, was found to freeze again, inſtead of paſſing out in the form of water, are impediments to its uſe. See the Philoſ. Tranſactions. T.

diſengaged from theſe bodies during their union, and in meaſuring the quantity of heat by that of the water which is formed, and which is to be collected with care. By this proceſs, they have been able to eſtimate with certainty the ſpecific heat of bodies, to meaſure the quantity abſorbed in certain combinations, and in ſhort to determine the quantity diſengaged in combuſtion and reſpiration.

The brevity we propoſe to adhere to in this work, and the long detail it would require to give a proper account of the ingenious inſtrument contrived by theſe learned academicians, and the manner in which they employ it to meaſure the ſpecific heat of bodies, as alſo that which is abſorbed or diſengaged in chemical combinations, oblige us to refer the reader to their own work *.

Let us here attend to the reſemblance which appears to exiſt, in certain caſes, between light and heat, and the differences which diſtinguiſh them in the proceſſes of nature and art. It is not to be concluded, that heat and light are the ſame thing, becauſe the rays of the ſun heat ſuch bodies as they fall on; for, ſince there are many caſes on the contrary, wherein there is much light without heat, as well as others where the heat is conſiderable, though no light appears. Many philoſophers are inclined to believe, that light differs greatly from heat. In fact, the phoſphorus, diamond, rotten wood, animal matters in putrefaction, ſhining inſects and worms, the rays of the moon reflected and concentrated by metallic mirrors, or by lenſes, preſent a ſtrong † light without ſenſible heat, and all natural bodies may be ſtrongly heated without becoming luminous.

The ſolar rays ſeem to produce heat merely by their impulſe on bodies, and the friction they ſuffer from ſuch as interrupt their paſſage. Opake bodies, of a red colour, and particularly when of a black colour, are found to be more quickly and ſtrongly heated, than white and poliſhed bodies; an effect doubtleſs ariſing from the greater refractions which the rays experience, and perhaps from its combining with the ſubſtance itſelf of theſe

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* See the Memoirs of the Royal Academy of Sciences for their Memoir, read June 28, 1783.

† All theſe, and other lights that do not produce heat, are prodigiouſly weak, when compared with the direct light of the ſun. The moſt concentrated moonlight, in the focus of a mirror, is not more than the 300th part of the intenſity of common ſun-ſhine. Heat cannot, therefore, be expected. See Traite d'Optique par Bouguer, quoted by Prieſtley in his Optics, p. 546. T.

deeply coloured bodies, while white ſurfaces reflect, rather than abſorb them [g].

As to the production of light by a ſtrong and continued heat, as is obſerved in the combuſtion of oils, fats, wood, the ignition of metals and ſtones, it depends on cauſes that by no means imply an identity between light and heat. When combuſtible bodies are ſtrongly heated, they produce that flame which ſupplies the abſence of the ſun, and produces ſimilar effects. But this light, the product of inflammation, may be contained either in the air, whoſe preſence is neceſſary for combuſtion, or in the combuſtible body; and no fact aſcertains that it is heat which is changed into light [h]. The incandeſcence of incombuſtible bodies, ſuch as ſtones, in which we cannot admit the preſence of combined light, at leaſt not in the ſame ſtate as in combuſtible bodies, has been explained in a very ingenious manner by Macquer, in the article Fire, in his valuable Dictionary. According to that chemiſt, it ariſes from the ſtrong vibrations excited in the particles of theſe bodies by heat. Theſe vibrations diſpoſe the particles in ſuch a manner that their facets being continually agitated, have the effect of a number of ſmall mirrors, which reflect, and throw directly to our eyes the light which exiſts in the air * in the night as well as in the day, and do not produce darkneſs, but when their directions are not towards the organs of ſight.

Such were the ideas of Macquer, and a conſiderable number of other philoſophers; but more numerous and better obſerved facts, concerning the difference of heat contained in various bodies, their aptitude to abſorb it, the elective attraction it appears to obey, render the opinion of the exiſtence of heat as a peculiar body, much ſtronger than ever. It is thought to be often one of the principles of compound ſubſtances; that it is the lighteſt of all natural bodies, and cannot, on that account, be ſhown to exiſt by any indication of weight. Two ſpecies of heat are diſtinguiſhed, or rather heat itſelf is diſtinguiſhed in two different ſtates, in all natural ſubſtances; one which is intimately combined, and is called latent heat, or caloric, becauſe it is not

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* The author has given Macquer's opinion, with fidelity and conciſeneſs; but the value of that opinion will be found to be very ſmall, when it is conſidered, that it is a neceſſary condition that his ſyſtem of little mirrors muſt be placed without the boundary of the earth's ſhadow, before they can receive or reflect the light which exiſts in the air, &c. T.

ſenſible, and the other which is ſimply diſſeminated. This laſt appears to be capable of expulſion by ſimple preſſure, or by mechanical means; thus it is, that when a bar of iron is hammered, and its particles are brought together by the ſhock, the heat eſcapes in the ſame manner as water flows out of a moiſtened ſponge by preſſure. Heat, truly combined, does not quit bodies but in conſequence of new chemical combinations. All ſolid ſubſtances which contain theſe two kinds of heat, are capable of taking up a greater quantity, both of the one and of the other; this ſuperadded heat ſeparates the particles more and more: Its firſt effect is to ſoften the ſolid body; its ſecond, in proportion as it is accumulated, conſiſts in fuſion, or liquefaction; its third, the quantity being ſuppoſed ſtill to be continually increaſed, is elaſtic fluidity. But we will treat of theſe phenomena in the two following paragraphs.

§ 3. *Concerning Rarefaction.*

The moſt remarkable effect attributed to fire by philoſophers, and which is certainly produced by heat, is rarefaction. We have already remarked, that the principal effect of heat is to augment the volume of all bodies, without adding to their weight. This rarefaction ſhows the intromiſſion of ſome ſubſtance into the pores of the rarefied body; this ſubſtance, which is heat itſelf, or rather caloric, acts like wedges or ſprings, that ſeparate and remove the particles of theſe bodies from each other; the bodies themſelves, when rarefied by heat, do not acquire weight, and their ſpecific gravity is leſs conſiderable than before, becauſe the rarefaction conſiſts ſimply in a ſeparation of the parts of the heated body, whoſe pores are then enlarged, ſo that it contains more void ſpace and leſs ſolid matter than before, in a given ſpace: This ſeparation is occaſioned by the matter of heat, whoſe weight, with reſpect to us, is nothing.

We ſhall be convinced that heat is a force oppoſed to the mutual attraction of the particles of bodies, and that it deſtroys their particular attraction, if we conſider that the particles of bodies rarefied by heat, experience an inteſtine motion which tends to diſunite and to ſeparate them; and that cold, on the contrary, compreſſes and condenſes them; for it muſt be remarked, that the attraction diſcovered by Newton, has three modifications, or modes of exiſtence, which require to be accurately diſtinguiſhed from each other. The firſt ſtate of attraction is that which, combined with an original impulſe, retains the planets in their orbits, and prevents them ſeparating from the ſun, with regard to which their diſtance would continually increaſe, did the projectile force act alone. To diſtinguſh it from the others, we may call this planetary attraction. The ſecond modification of attraction, is that which cauſes bodies projected into the atmoſphere, to tend towards the centre of the earth. This is terreſtrial gravitation. And the third modification of this general force, is that by which the different parts of any particular body as a ſtone, or any compact ſubſtance, tend towards their centre. It is the attraction which produces aggregation, and which heat tends to deſtroy; and by diminiſhing this, it produces a great number of effects, combinations, decompoſitions, vegetation, animalization, &c.

Boerhaave, who has conſidered the effects of fire rather as a philoſopher than as a chemiſt, has laid down three rules, or laws, concerning rarefaction conſidered in general, which we will now proceed to examine.

LAW I.

All Bodies are dilated by Heat *.

Though it be true in general, that almoſt every body in nature is dilated and rarefied by heat, it is neceſſary to make ſome remarks on this phenomenon. In the firſt place, all mineral ſubſtances without exception, experience a dilatation, which is greater, the more intenſe the heat [i]. This rarefaction is ſuch as to deſtroy the aggregation of a great number of them. But if this law be applied to animal and vegetable matter, it appears to be ſubject to ſome exceptions. In fact, a gentle heat really dilates their fibres, ſeparates them, and diminiſhes the denſity of their texture; but by a ſudden and ſtrong heat, parchment, membranes, and tendons, ſhrink and contract; a property which ſeems to depend on the irritability, or rather the contractability of animal fibres, to which heat ſeems to be a ſtimulus, as long as their organization is not deſtroyed.

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* This law is univerſal in bodies, ſo long as they retain the ſtate of ſolidity, fluidity, or vapour they happen to poſſeſs; and have ſuffered no change either in the combination or quantity of their chemical principles. If the rule be taken in this ſenſe, the exceptions of our author will not ſtand. T.

LAW II.

Bodies rarefied by Heat, have all their Dimenſions enlarged.

A bar of iron increaſes both in length and thickneſs when heated. Philoſophers have contrived many inſtruments to exhibit and meaſure this effect of rarefaction. The pyrometer invented by Muſchenbrock, ſhows the dilatation of heated metallic bars to the 12,500 of an inch. This ſenſibility is obtained by the motion of expanſion being communicated through ſeveral levers, whoſe arms are of unequal length; ſo that the extremity of the laſt is moved through a ſpace ſufficiently large to give motion to a wheel, which carries an index or hand round a graduated circular plate, and ſhows the minuteſt changes of length in the bar under examination. But as this inſtrument is uſed only to ſhow the expanſion of metallic bars lengthwiſe, philoſophers have made an experiment with a cylinder of metal fitted to an orifice in a metallic plate, ſo as juſt to paſs through it when cold, and they find, that the ſame cylinder, when heated, could not paſs. It is therefore eſtabliſhed, that bodies expand by heat in diameter, as well as in length[k].

This phenomenon is well known to chemiſts, who find it neceſſary to leave ſufficient room in the iron grates they place in their furnace, and not to preſs too cloſely ſuch veſſels as are luted together; for, without that precaution, it would not be poſſible to avoid the fractures and inconveniencies which their expanſion would produce.

LAW III.

The Dilatation by Heat is directly as the Rarity, or inverſely, as the Denſity of Bodies.

Boerhaave, in the eſtabliſhment of this law, compared the effect of heat on no more than three ſolid bodies, and theſe very different from each other, namely, wood, ſtone, and metal. He obſerved, that wood dilated moſt, next ſtone, and then the metal, and that the rarefaction of the particles of theſe bodies followed the inverſe ratio of their denſity. From thence he concluded, that the rarer the texture of any body, the more it will be dilated; and the denſer, the leſs will be the degree of its dilatation. But M. Buffon, in repeating the experiment of the rarefaction of a great variety of ſolid bodies by heat, found, that heat dilates them in proportion to their ſuſceptibility of alteration by fire. That is to ſay, ſtones, in proportion to their calcinability, and metals, in proportion to their fuſibility. Boerhaave extended this law to fluids, on no better ground than trials made with air, ſpirit of wine, and water. If he had brought mercury into the compariſon, he would not have generalized his law; for, though much more denſe than either the ſpirit or the water, its dilatation is greater. This experiment proves, that neither the quickneſs of becoming heated, nor the degree of expanſion, is governed by the inflammability, or by the fuſibility of the matter under conſideration. Meſſrs. Bucquet and Lavoiſier, who have made a long courſe of experiments on the dilatation of fluids by heat, and its progreſs, have not been able to diſcover the cauſe of the ſingular diverſity they have obſerved, and have contented themſelves with deſcribing the facts without drawing any inferences.

In addition to the laws of the rarefaction which heat produces, and which are far from being yet well underſtood, it is eſſential to know, 1. That all bodies, in paſſing from the ſolid to the fluid ſtate, or from fluidity to vapour, produce cold, as ſalts by ſolution in water, ether by evaporation[1], &c. 2. That fluids, capable of becoming concrete, produce heat in paſſing to the ſolid ſtate. Thus water, which freezes by being placed in a freezing mixture, never becomes ſo cold as ſpirit of wine plunged in the ſame mixture. It may be conceived, from what is here expoſed, that this general effect depends on the circumſtance, that a ſolid body which becomes liquid, abſorbs more heat than it before poſſeſſed; whereas, in the contrary circumſtance, it gives out the quantity of heat which kept it in a ſtate of fuſion.

§ 4. *Concerning the Phlogiſton of Stahl.*

Beccher, ſtruck with the wonderful property certain bodies poſſeſs of producing fire, that is to ſay, heat and light, by repeated motion, or by the contact of other bodies in a ſtate of ignition, concluded, that it depended on a particular principle, which he called inflammable earth. Stahl, whoſe attention was ſtrongly fixed on this doctrine, imagined that this principle was pure fire, or the matter of fire fixed in combuſtible bodies, and gave the name of phlogiſton, or the inflammable principle, to this element thus combined; in order to diſtinguiſh it from fire in action, or in a ſtate of liberty. Its properties, when in combination, are, therefore, very different from thoſe it poſſeſſes when at liberty; ſo that it can no longer be known by its two diſtinguiſhing criterions, heat and light. But it reſumes them when ſeparated from the bodies which confined it, and appears again with all the brilliancy and heat which accompany it when ſet free. Such was the ſimple and ſublime idea of Stahl on the nature of combuſtible bodies. It is, in fact, natural to think that ſuch matters, as by becoming once ſtrongly heated, take fire, and continue to burn till entirely conſumed, owe this property to fire concealed within them; and that combuſtion is nothing more than a proceſs by which this fire is developed. All inflammable bodies, therefore, according to Stahl, contain fixed or combined fire, which is the principle of their inflammability. Hence he regarded the inflammable principle as identical in all bodies that contain it, whatever be their nature, or however they reſpectively differ from each other. Nothing more was required than the property of combuſtibility, to prove the preſence of phlogiſton in large quantity. Thus, ſulphur, coal, metals, oils, phoſphorus, &c. owe their inflammability to fixed fire, and the differences of ſtructure, form, colour, conſiſtence, weight, &c. depend on the various principles with which the phlogiſton is united; this laſt being univerſally the ſame, except when, by changes of ſtate, it becomes free or uncombined.

To arrive at a knowledge of the properties of fixed fire, or phlogiſton, Stahl made a compariſon between ſuch bodies as contain it, and others into which it does not appear to enter. He obſerved, that the firſt in general poſſeſſes colour, ſmell, fuſibility, volatility, and combuſtibility; while the latter are uſually colourleſs, without ſmell, more or leſs fixed, infuſible, and more eſpecially incombuſtible. He has alſo taken notice, that bodies, manifeſtly abounding with phlogiſton, loſe the greater part of the properties common to them as ſuch, on being deprived of that principle, and have them reſtored upon being again furniſhed with phlogiſton.

It was more eſpecially from the conſideration of experiments made with ſulphur and metallic ſubſtances, that he eſtabliſhed his doctrine with ſucceſs. Metals, according to him, are compounds of peculiar earths united to phlogiſton. When they are calcined, their phlogiſton becomes diſengaged, in the form of fire at liberty; in conſequence of which they are no longer fuſible, ductile, or inflammable. Theſe properties are reſtored when the earths are again united to phlogiſton, by heating them with oils, coal, or any other matter abounding with that principle. Sulphur is compoſed of the vitriolic acid united to phlogiſton. Its combuſtion diſengages and diſſipates the latter; the acid only remains. If this acid be treated with coals, oils, or metals, it deprives them of their phlogiſton, and again forms ſulphur, which is a coloured, odorant, fuſible, volatile, and inflammable ſubſtance.

The difficulties attending the doctrine of phlogiſton may be compriſed under three claſſes. 1. The properties Stahl has attributed to this principle, are not univerſally found in thoſe bodies which he affirms to contain it. Charcoal, and in particular that of reſins, which he regards as being almoſt pure phlogiſton, is poſſeſſed neither of ſmell, volatility, or fuſibility. There are even ſome charcoals which are not very combuſtible. Diamond, a ſubſtance very infuſible, fixed, tranſparent, inodorous, is perhaps the moſt inflammable ſubſtance we know, ſince it burns totally, and without reſidue. Spirit of wine, ether, and many eſſential oils have no colour.

2. It often happens, that bodies in loſing their phlogiſton acquire the very properties Stahl commonly attributes to its preſence, and which were ſcarcely obſervable in the body before. Moſt metallic bodies, by calcination, acquire a deeper colour, as may be inſtanced in cobalt, mercury, lead, iron, copper, &c.

3. Stahl, in his great attention to combuſtible bodies, from the nature of which he endeavoured to aſcertain that of phlogiſton, has paid very little regard to the abſolute neceſſity for the preſence of air in combination; and ſeems to have forgotten how eſſential it is to that proceſs. It is in conſequence of this, that he has not foreſeen the ſtrongeſt objection that could be made to his theory; but which, however, was not propoſed by any chemiſt of his time. If combuſtion be nothing more than the diſengagement of phlogiſton, it is clearly a decompoſition, in which the inflammable body loſes one of its principles. But is it poſſible that a body, by the loſs of one of its principles, ſhould become abſolutely heavier than before? Yet it is true, that one hundred pounds of lead afford an hundred and ten of minium; and that ſulphur, by combuſtion, affords more than its own weight of vitriolic acid. And in the ſame manner, ſixteen ounces of ſpirit of

wine, by being burned, affords eighteen ounces of pure water, according to the happy diſcovery of M. Lavoiſier.

The force of this objection, added to the difficulty of proving the exiſtence of phlogiſton, have induced ſome modern chemiſts to deny its exiſtence altogether. This, however, muſt be underſtood with ſome reſtriction; for, notwithſtanding the immenſe reſearches made of late years into the phenomena of combuſtion, the opinion which admits the exiſtence of fire as a principle fixed in bodies, has not yet been overthrown, and its name of phlogiſton has been changed into that of caloric or combined heat. But it is not to this matter that the property of combuſtibility is attributed. Its preſence in inflammable bodies is not that which determines their inflammability.

Since the attention of chemiſts has been directed to the neceſſity of air to combuſtion, many important diſcoveries have been made; the principle of which is, that a portion of atmoſpheric air is abſorbed by bodies that burn, and that it is this part of the air, which, becoming fixed or combined, increaſes the abſolute gravity of metals, ſulphur, phoſphorus, inflammable air, and ſpirit of wine, after their combuſtion. And it has likewiſe been diſcovered, that this augmentation correſponds accurately to the weight of the air abſorbed. Some chemiſts, at the head of whom Meſſrs. Lavoiſier and Bucquet may be placed, have admitted a new theory, entirely founded on the abſorption of air, and wherein no mention is made of phlogiſton. This theory is directly oppoſite to that of Stahl, and is comprehended in the four following principles:

1. The bodies, called phlogiſticated by Stahl, are, according to this doctrine, bodies which have a ſtrong tendency to unite with air; a tendency which in general conſtitutes combuſtibility.

2. All the facts or circumſtances in which Stahl ſuppoſed phlogiſton to be diſengaged, conſiſt of nothing more than the entering of pure air into combination. Such are combuſtion, calcination, reſpiration, the formation of the vitriolic and phoſphoric acids by the combuſtion of ſuphur and of phoſphorus.

3. Every circumſtance, on the contrary, wherein phlogiſton enters into combination, according to Stahl, conſiſts of nothing more, in the pneumatic theory, than the diſengagement of air. Such are the production of metals effected by the reduction of metallic calces and charcoal, the decompoſition of acids by

combuſtible bodies, and in particular thoſe of the vitriolic and nitrous acids by iron, charcoal, &c.

4. Every matter which Stahl ſuppoſes to be a compound, containing phlogiſton, is regarded in this theory as a ſimple ſubſtance, which has a ſtrong affinity with pure air, and endeavours to combine with it whenever they come into contact. So that combuſtion conſiſts in a combination of air with the combuſtible body; and every operation, in which bodies have been thought to regain phlogiſton, is ſimply either the diſengagement of pure air, or its paſſage from one body to another.

This opinion, adopted by the late M. Bucquet, in his latter courſes of lectures, explains the greater part of the phenomena of combuſtion, calcination, and reduction of metallic calces; but it does not afford adequate reaſons for the flame which is produced by bodies in a ſtate of ignition, nor the rapid motion and other changes that attend it. M. Macquer, who muſt have been well aware of the influence of the modern diſcoveries on chemical theory, was of opinion that they do not entirely overthrow that of Stahl, and has found means to unite the pneumatic doctrine we have here explained with that of phlogiſton, by conſidering this principle as light fixed in bodies. After having ſhown that pure light, ſuch as is emitted by the ſun, may be regarded as the true matter of fire, and that by admitting it as fixed in bodies, it conſtitutes the phlogiſton of Stahl, he conceives that in every inſtance of combuſtion, the pure air diſengages the light or phlogiſton from inflammable bodies, and occupies its place; ſo that calcination may be regarded as the precipitation of air, and diſengagement of light. When, on the contrary, phlogiſton is reſtored to neutral ſubſtances, the matter of light ſerves to diſengage in its turn the air fixed in thoſe bodies, by which means they again reſume the metallic ſtate. In this theory, which perfectly anſwers the intention of its author, by uniting the doctrine of Stahl with that of the moderns, Macquer thinks that phlogiſton can unite with bodies even in cloſed veſſels, becauſe light, which he regards as the true phlogiſton, paſſes through glaſs veſſels, as every one knows, and even penetrates metallic or earthen veſſels when heated to ignition. Scheele has propoſed a different theory, which has had its adherents among the northern chemiſts. He ſuppoſed that fire, heat, and light, were compounds of vital air and phlogiſton; that, by paſſing through the veſſel, the light was decompoſed, it depoſited its phlogiſton, and the vital air was diſengaged as in the reduction of the metallic calces or oxyds. But this ingenious theory, by the aſſiſtance of which Scheele explained the influence of ſolar light and heat differently modified, in a great number of chemical phenomena, does not afford the reaſon of the increaſe of weight in metals, ſulphur, phoſphorus, &c. after their combuſtion.

Lavoiſier, whoſe opinion ought to have as much weight in chemiſtry as his experiments have had influence on its progreſs, has offered a new doctrine, which many French chemiſts have adopted, and which appears to me to explain, the moſt perfectly of all the phenomena of nature. He thinks that light, heat, and all the great phenomena which combuſtible bodies preſent in their inflammation, depend more upon the air which favours this laſt proceſs, than on their own proper nature; that the flame which takes place in this operation, ariſes rather from the light diſengaged from the pure air, than from that which is ſeparated from the combuſtible body. The decompoſition which takes place, according to Stahl and Macquer, in the inflammable ſubſtance, is by him attributed to the pure air, which he conſiders as a compound of the matter of fire, and another principle we ſhall hereafter ſpeak of; and the fixed fire, whoſe diſengagement produces the principle effect, is, according to him, ſeparated from the pure air rather than from the combuſtible body. We cannot enter more fully in this place into this ingenious ſyſtem; we ſhall dwell more largely upon it in the hiſtory of air, which belongs to the following chapter. We ſhall content ourſelves by obſerving, that the matter of fire or heat, which Lavoiſier admits in pure air, and whoſe diſengagement is, according to him, the cauſe of the dazzling flame and ſtrong heat which attend the rapid combuſtion produced by this air, performs nearly the ſame office as the phlogiſton of Stahl, or the fixed light of Macquer, and that all chemiſts are agreed concerning its exiſtence; but that they differ in this, that ſome admit its exiſtence in the combuſtible bodies, and conſider it as the cauſe of inflammability; others think that it exiſts in the air, and that it is not the ſubſtance which determines the combuſtibility. We ſhall, in the following chapters explain the reaſons which lead us to think, that this laſt opinion is the moſt probable [m].

§ 5. *The Effects of Heat on Bodies conſidered Chemically.*

It has been ſeen, that one of the principal effects of heat, is the rarefaction of bodies, that is to ſay, the augmentation of their bulk, by increaſing the diſtance between the particles, and a conſequent diminution of their ſpecific gravity. This, is the ſimple, phyſical, or mechanical idea, we have exhibited in ſpeaking of rarefaction in general; but when this action is more carefully attended to, we find its other conſequences are ſuch, that it becomes of eſſential conſequence to underſtand them.

The firſt and moſt ſtriking chemical conſideration that preſents itſelf, is, that heat, by removing the particles of bodies farther apart, diminiſhes their aggregation. The force of aggregation and the affinity of compoſition being always oppoſed to each other, as has been ſhown in the third chapter, it is eaſy to conceive that fire or heat ſingularly favours * combination, by deſtroying aggregation. This effect has cauſed fire to be regarded as the principal agent of the chemiſts, and they have themſelves aſſumed the title of philoſophers by fire. We ſhall ſee, however, that they avail themſelves much leſs of its aſſiſtance than they formerly did.

The action of heat conſidered under this point of view, as tending to deſtroy aggregation, and to favour combination, ſeems to be modified in four different manners, according to the nature of the bodies on which it exerciſes its power.

1. There are bodies which it only dilates, during the time of its continuance, without altering them in any other reſpect; theſe are called apyrous: Thus it is found that rock cryſtal †, expoſed to the ſtrongeſt and moſt powerful heat, continued for a long time, ſuffers no alteration, either in hardneſs, tranſparency, or any other property, and comes forth from this trial as denſe and

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* The ſimple removal of particles from each other, may favour combination, by enlarging the intervals through which other particles muſt paſs, in obeying the laws of affinity; and there may be many affinities too weak to act without this aſſiſtance. T.

† It has been melted by flame, urged by a ſtream of dephlogiſticated air. T.

as beautiful as ever. There are few ſubſtances equally unchangeable by fire [n].

2. Heat entirely deſtroys the aggregation of many bodies, cauſing them to paſs from the ſolid to the fluid ſtate. This phenomenon is called fuſion, and the bodies which undergo it fuſible. There are different degrees of fuſibility, from that of platina, which is exceedingly difficult to melt, to that of mercury, which in our climate is always fluid. This fuſibility, carried to the extreme, is volatility. A body is volatilized, or riſes into the atmoſphere, when it paſſes from the ſtate of liquidity, by a high degree of rarefaction, to that of an elaſtic fluid. Being then lighter than the atmoſpheric air, it aſcends, and remains ſuſpended, or diſſolved, until condenſed by cold. Bodies poſſeſſed of this property, are ſaid to be volatile. Thoſe which do not poſſeſs it are called fixed. There are many gradations between fixity and volatility. It ſeems indeed that there are no bodies abſolutely fixed, and that they are only relatively ſo with reſpect to our fires, but would riſe at greater heats than at preſent we know how to excite. The ſame obſervation applies alſo to infuſibility. The cauſe why rock cryſtal cannot be fuſed, is ſimply, that we cannot excite a ſufficient degree of heat. The infuſibility and fixity of bodies is therefore merely comparative amongſt each other, and with reſpect to our fires.

This eſſential property of volatility muſt be well diſcriminated from another kind, which is only apparent. The current of heated air, or exploſions of flame, may raiſe bodies in a ſtate of minute diviſion, though not volatile in themſelves. Thus the calx of zinc is raiſed by the rapid motion of the flame which is produced in burning that ſemi-metal.

3. When heat acts on bodies compoſed of two principles, one of which is volatile, and the other fixed, it ſeparates them by volatilizing the former. Theſe bodies are decompoſed without alteration; ſo that they may be compounded again, and all their properties made to re-appear by uniting them. This ſeparation of conſtituent parts, is the true or ſimple analyſis. Fire applied to bodies compoſed of two ſubſtances differing greatly in their degree of volatility, reduces the very volatile ſubſtance to the ſtate of vapour, while the fixed remains unaltered. In order that this analyſis may take place, it is a neceſſary condition that the

fixed, as well as the volatile ſubſtance, be unalterable by the heat applied; or that the heat to which they are expoſed, be not raiſed ſo as to change completely their properties. In that caſe, the volatile ſubſtance having undergone no greater alteration than the fixed, they may be united together ſo as to produce a compound the ſame with that which exiſted before its decompoſition. It is this alone that indicates that a true or ſimple analyſis has been effected. But as it ſeldom happens, that bodies are compoſed of two ſubſtances, the one volatile and the other fixed, and as it is often difficult, and even ſometimes impoſſible to regulate the heat ſo as to ſeparate the more volatile, without changing the nature of the fixed; it is eaſy to conceive, that the number of bodies thus acted on by heat, is very ſmall. This is the reaſon why chemiſts make leſs uſe of fire in their operations than they did formerly. The ſubſtances on which heat produces this effect, are ſaid to be decompoſable without alteration. Certain mineral matters, ſuch as cryſtallized ſalts, and ſolutions of neutral ſalts, belong to this claſs.

4. If the bodies expoſed to heat be compoſed of ſeveral principles, both fixed and volatile, the volatile principles combine together, as do alſo the fixed; ſo that the decompoſitions afford new products, which cannot form the original compound by reunion. This is the falſe or complicated analyſis; and bodies thus acted on by heat, are ſaid to be decompoſable with alteration.

The greateſt number of natural ſubſtances are of this kind; becauſe they are compoſed of too great a number of principles to admit of the action of heat, without new combinations taking place, as well as decompoſitions. Since the force of the affinity of compoſition exiſts in all bodies; ſince it is even aſſiſted by heat, in proportion as the principles of a compound of this nature are volatilized by the fire; they re-act on each other, unite and form an order of combination different from that which exiſted formerly: The ſame kind of union takes place alſo among the fixed principles of the body. Thus we find, by expoſing a piece of wood, bark, or other vegetable matter, to the action of heat, the oily matter and the charcoal, which are the component parts, decompoſe a portion of the contained water, and form an acid, elaſtic fluids, and a brown oil, which did not exiſt as ſuch in the wood, &c. Every part is therefore changed by the action of the heat, and the phenomena announce a falſe and complicated analyſis, whoſe reſults would miſlead chemiſts, if they were not aware of its uncertainty and inſufficiency. It is certain that art cannot produce again any vegetable ſubſtance, by mixture of the phlegm, oil, acid, and coal obtained by an analyſis of this kind, becauſe the principles it affords have ſuffered very conſiderable changes. It is unfortunate that the greater number of bodies are ſubject to this kind of change by heat. Every animal and vegetable ſubſtance, and a great quantity of mineral matters, belong to this claſs; but the modern diſcoveries are able to determine the true nature of the principles which conſtitute theſe matters, from the conſideration of thoſe which are diſengaged.

Thus far we have ſpoken only of a ſtrong heat, ſuch as is commonly applied in the different operations of art; but a low degree of heat, long continued, produces in the operations of nature a great number of phenomena, which the chemiſt ought to attend to, and endeavour to underſtand. The vibrations excited by the preſence of heat, in the ſolid parts of bodies, and the rarefaction and agitation produced in the fluids, keeps up a continual inteſtine motion, which by degrees changes the form, the dimenſion, and ſtructure of the former, and ſenſibly alters the conſiſtence, colour, taſte, and, in a word, the intimate nature of the latter. This is the general idea we may form of the exiſtence and effect of the chemical operations that take place in natural bodies, of the ſpontaneous decompoſition and re-combination of minerals, with the cryſtallization, ſolution, and formation of ſalts, the vitrification, and metalization, the vitriolization, and mineralization that take place in the interior parts of the globe we inhabit. It is to the powerful agency of heat, likewiſe, that we muſt recur, to account for the alterations of which the bodies of vegetables and animals are ſuſceptible, the motion of the ſap, the mild fermentation which produces maturation or ripeneſs in fruits, the formation of oils, of the ſpiritus rector, of mucilages and of the colouring principle, the compoſition of animal fluids, their decompoſition, reciprocal changes and putrefaction. All theſe important phenomena are produced by chemical operations; and the heat diffuſed over our globe is the governing principle. Our preſent intention is ſufficiently anſwered, by the tranſient view we have taken of this common ſource of motion, life, and death. We have here given a ſketch of the ſubject, and ſhall endeavour, in the following ſheets, to exhibit its parts with accuracy.

As theſe various effects of heat ariſe from the ſeparation which it produces between the particles, let us again conſider this firſt effect, and endeavour to appreciate its whole influence.

Water in the form of ice is ſoftened by a certain degree of heat, as appears by its being leſs elaſtic; a greater degree of heat melts it; and laſtly, it becomes ſtill more fluid, if the term may be uſed, when a ſtronger degree of heat reduces it into vapour, or elaſtic fluid; ſo that the vapour of water may be ſaid to contain a total ſum of heat, conſiſting of the quantity neceſſary to conſtitute ice of a certain denſity, added to the quantity neceſſary to produce the ſtate of liquidity; and laſtly, the quantity neceſſary to maintain the ſtate of elaſtic fluidity °.

This general theory may be applied to all the bodies in nature; there is no one which may not be conſidered as capable of paſſing through all theſe ſtates by the aſſiſtance of a ſufficient degree of heat, and as far as relates to this property, they do not appear to differ from each other, but in the quantities of heat neceſſary to produce the changes reſpectively in each. It is for want of a ſufficient degree of heat, that rock cryſtal can neither be melted, nor brought into the vaporous ſtate; and it is no more difficult to conceive the poſſibility of this being effected, than it is to conceive that the fluid we always ſee in a ſtate of elaſticity, namely, the air may acquire a great degree of ſolidity, as in fact happens in many combinations.

It is eaſy on theſe principles to explain the formation of elaſtic fluids, which are diſengaged in a great number of the operations of nature and art. It takes place every time that a body receives and abſorbs a ſufficient quantity of heat to cauſe it to paſs to the ſtate of diviſibility, which conſtitutes aeriform fluidity, and which takes place whenever bodies receive and abſorb ſufficient quantities of heat. All aeriform fluids owe their elaſtic property to the matter of heat; but the preſſure of ſurrounding bodies, and more eſpecially that of the air, is required to be removed or diminiſhed before this ſtate of extreme dilatation can take place, and if the weight of the atmoſphere be entirely removed, as happens in the vacuum of the air pump, a body at a much lower temperature than would have been neceſſary to have produced the elaſtic ſtate in the open air, may immediately become elaſtic. This accounts for the more rapid evaporation which takes place on lofty mountains; and hence we may perceive the neceſſity of mentioning, in the account of experiments, at what degree of external preſſure bodies have taken the form of elaſtic fluid, or at leaſt the degree of preſſure under which they can preſerve it. For it muſt be obſerved, that all bodies capable of taking this ſtate of elaſtic fluidity, are not equally diſpoſed to preſerve it, and that in this reſpect the differences between them are ſo great, that they have been diſtinguiſhed into permanent and non-permanent. The former remain elaſtic during a very long ſpace of time, and till ſome combination takes from them the matter of heat neceſſary to maintain their ſtate; the ſecond, which are denoted by the name of vapour, loſe the elaſtic fluidity by a degree of preſſure or refrigeration eaſy to be determined, and give out to all the ſurrounding bodies the matter of heat, which maintains their aeriform ſtate; ſuch are water, ſpirits of wine, ether, &c. Theſe three fluids are reduced into vapours, and preſerve their aerial form, when the barometer ſtands at 28 inches, and the water poſſeſſes the temperature of 80° of Reaumur's thermometer, ſpirit of wine 66°, and the ether 32°.

It appears then, 1ſt, That the ſtate of elaſtic fluidity is a mode of the exiſtence of bodies occaſioned by combined heat. 2. That every elaſtic fluid is compounded of a baſe more or leſs ſolid, and the matter of heat. 3. That each of theſe baſes require more or leſs heat to reduce them into the ſtate of vapour or elaſtic fluid; and that it is doubtleſs in conſequence of theſe properties that all elaſtic fluids differ from each other in their ſpecific gravity, elaſticity, &c.

Mr. Lavoiſier has explained this theory in a very perſpicuous manner, in a memoir printed among thoſe of the academy in 1777.

Though we have divided elaſtic fluids into permanent and non-permanent, it muſt be obſerved, that this diſtinction does not really exiſt in nature, that it relates only to the heat and degree of preſſure which are experienced in our climates, and in moſt of the habitable parts of the globe; and that if the cold and preſſure were more conſiderable, thoſe fluids, which are now taken to be the moſt permanent, would ſoon ceaſe to be ſo; and in the ſame manner, for the contrary reaſon, ether and ſpirit of wine would become permanently elaſtic fluids at a certain height in the atmoſphere, or at the high temperatures of certain climates, ſituate beneath the equator, &c.

The matter of heat, which contributes to the formation of permanently elaſtic fluids, is intimately combined with them, or latent, and does not become ſenſible, till theſe bodies loſe this fluidity by combining with other ſubſtances. We have ſought for an expreſſion which might denote this ſtate of combination in heat; we have adopted the word caloric, becauſe, in fact, when this body is fixed, it is no longer heat, but becomes ſo only when ſet at liberty. This denomination likewiſe avoids the periphraſes of the matter of heat, or latent heat, which have been the expreſſions hitherto uſed. Cooling, or the tranſition of heat to the ſtate of caloric; heating, or the tranſition of caloric to the ſtate of heat,—depend on the general law we have eſtabliſhed. Whenever an aeriform fluid or gas combines in ſuch a manner as to become liquid or ſolid, it loſes a great quantity of the matter of heat it before contained; and in order that it may paſs to this ſtate of denſity, it is neceſſary to preſent a body which has a greater affinity with its baſe than that baſe has with heat. Such in general is the cauſe of the fixation of elaſtic fluids; and in this manner do they loſe that form by becoming fixed or ſolid in liquid bodies; it may be further obſerved, that each of theſe fluids loſes or ſuffers the diſengagement of different quantities of heat, accordingly as it becomes more or leſs ſolid in its new combination, or accordingly as that combination is capable of retaining more or leſs ſpecific heat. This obſervation ſerves to explain the difference between the ſeveral kinds of combuſtion, which are more or leſs rapid, accompanied with greater or leſs heat and flame, and leave reſidues of various degrees of ſolidity, &c. phenomena which ſhall be mentioned in the following chapter.

Laſtly, If preſſure and cold be the two means of condenſing all elaſtic fluids, we may, perhaps, by employing ſtrong degrees of both, ſucceed in cauſing them to loſe their gaſeous ſtate, and obtain the baſes ſeparate and pure, by excluding the matter of heat which kept them in ſolution. By this means we ſhould become acquainted with the baſes of vital air, of azotic gas, of hydrogen gas, &c. This has already been done with ſucceſs in one inſtance by Mr. Monge, who has reduced the ſulphureous acid gas to a ſtate of liquidity by the application of a great degree of cold [p].

§ 6. *Concerning Fire, conſidered as a Chemical Agent, and the Method of applying it to Bodies.*

The different changes produced in bodies by heat, are employed by chemiſts in decompoſing or combining bodies. The firſt circumſtance to be attended to, is to have an exact meaſure of the degrees of heat neceſſary to effect the changes, of which the matters under examination are ſuſceptible. The degrees of heat are generally conſidered under two principal diviſions; one comprehending thoſe under the temperature of boiling water, and the other ſuch as are above that temperature. The ſcale of the thermometer ſerves to diſtinguiſh the former; the latter, for the greateſt part, can be eſtimated only from the fuſibility of different ſubſtances [q].

Diviſions of Heat below the Boiling Water Point.

The firſt diviſion extends from 45° to 60° of Fahrenheit *. This temperature favours putrefaction, vegetation, ſlow evaporation, &c. It is not commonly uſed in chemiſtry, becauſe not conſiderable enough; except in certain macerations made during winter, or for the cryſtallization of ſaline mixtures, after due evaporation, placed in caves, or other ſituations of this temperature.

The ſecond diviſion, extending from about 68° to 80°, continues to promote putrefaction. It excites the ſpirituous fermentation in ſaccharine liquors, and facilitates evaporation, and the ſlow cryſtallization which follows. This is the ordinary heat of temperate climates. It is uſed for digeſtion, ſaline ſolutions, fermentations, &c.

The third diviſion lies between the 88th and 100th degrees of the thermometer. In this temperature the acid, or acetous fermentation in vegetables, is beſt carried on, and plants are ſucceſsfully dried for practical uſe. It is uſed for certain ſaline ſolutions, and to promote fermentations.

The fourth diviſion is at, or near, the temperature of about

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* Reaumur's ſcale is uſed in the original. T.

145°. It is called the mean degree of heated water, and is that of the veſſels called balneum mariæ. It deſtroys the organization of animal matters, and volatilizes the more ſubtile parts of eſſential oils, eſpecially the ſpiritus rector. It is uſed in the diſtillation of vegetables and animal matters, whoſe phlegm and principle of ſmell are intended to be ſeparated.

The temperature of boiling water, or 212° is uſed in decoctions, the extraction of eſſential oils, &c.

Diviſions of Heat above Boiling Water.

The firſt diviſion melts ſulphur, burns organized matter, or gives a low red heat to glaſs veſſels.

The ſecond extends from the fuſion of the ſofter metals, ſuch as lead, tin, or biſmuth, to that of the ſofter kinds of glaſs.

The third diviſion may be conſidered as including the fuſion of metals of a middle conſiſtence, ſuch as antimony, ſilver and gold.

The fourth ſerves to bake porcelain, and fuſes the more refractory metals, ſuch as cobalt, copper, iron, &c.

The laſt and higheſt of all is found in the focus of the burning glaſs. This extreme heat calcines, burns, and vitrifies, in a very ſhort time, all bodies ſuſceptible of ſuch a change. A ſimilar degree of heat may be excited by a ſtream of vital air or oxygenous gas thrown upon charcoal, by means of the bellows or blowpipe. M. Monge is of opinion, that by preſenting atmoſpheric air in a ſtate of compreſſion, to combuſtible bodies in a ſtate of inflammation in the furnace, an effect may be produced ſimilar to that excited by vital air. This proceſs may hereafter be applied to operations in the large way.

Though theſe diviſions above boiling water are determined by phenomena well known to chemiſts, their admeaſurement has not the deſired preciſion. An inſtrument capable of indicating with exactneſs the degrees employed in theſe operations, would be an acquiſition of great value and importance. Mr. Wedgwood has conſtructed in England a thermometer of this nature; it is formed of ſmall pieces of clay half an inch in diameter. Theſe pieces, when contracted by heat, advance to a greater or leſs diſtance between two rules of copper convergent towards each other, upon a plate of the ſame metal. In this manner, by means of a ſcale drawn upon theſe rules, the degree of contraction, and conſequently of heat, which they have experienced, is aſcertained. *Journal de Phyſique*, 1787[r].

The heat required in chemical operations, is produced by the combuſtion of charcoal, or common mineral coal. For this purpoſe, various furnaces of different forms and names are conſtructed, according to the purpoſe they are intended to anſwer. Such are the furnace for digeſtion, for fuſion, the reverberating furnace, the wind furnace, the cupelling furnace; and it is poſſible, by a ſkilful attention to various particulars, to conſtruct a furnace capable of anſwering the intentions of every kind. It is then called a polycreſt furnace. On this ſubject the chemical dictionary of Macquer may be conſulted, where the author deſcribes a peculiar and very uſeful furnace of his own invention: Alſo the chemiſtry of Baumé, the Lithogeogneſia of Pott, the Journal de Phyſique of the Abbé Roſier, in which the deſcription of many furnaces, conſtructed by various chemiſts, may be found. The flame of oil and ſpirits of wine is ſometimes employed in lamp furnaces adapted to that purpoſe.

The manner of communicating heat to bodies in the various chemical proceſſes, likewiſe deſerves to be conſidered. If the combuſtible matter itſelf be applied to the ſubſtance itſelf, or the veſſel immediately containing it, the operation is ſaid to be performed by a naked fire. If any ſubſtance be placed between the fire and the veſſel containing the matter under examination, the interpoſed ſubſtance is called a bath. Hence the names balneum mariæ, or water bath, ſand bath, dung bath, cinder bath, &c.

The form of the veſſels employed in the treatment of bodies by fire, and the different phenomena preſented by the matter expoſed to its action, have occaſioned a conſiderable number of operations to be diſtinguiſhed by particular names. Such as roaſting, calcination, fuſion, reduction, vitrification, cupellation, cementation, ſtratification, detonation, decrepitation, fulmination, ſublimation, evaporation, diſtillation, rectification, concentration, digeſtion, infuſion, decoction, lixiviation. Theſe operations performed by the aſſiſtance of fire, conſtitute the practical part of chemiſtry, of which we ſhall proceed to give a ſhort account.

Roaſting is a proceſs by which mineral matters are divided, ſome of their principles being volatilized, and others changed, ſo as to prepare them for other operations, to which this may be regarded as preliminary. Minerals are ſubjected to this, in order to ſeparate their ſulphur or arſenic, and to render them more pulvereble or friable. In the ſmall way, this is done in crucibles, roaſting nets, or capſules of earth or iron, and generally with acceſs of air. Sometimes it is performed in cloſed veſſels, for which purpoſe two crucibles are uſually luted mouth to mouth.

Calcination is, as it were, a more advanced ſtage of the proceſs of roaſting. Minerals are by this deprived of their water, calcareous ſtones are thus converted into lime, and the metals into metallic oxyds. The ſame veſſels are employed for this purpoſe as for roaſting.

By fuſion, bodies are made to paſs from the ſolid to the fluid ſtate, in conſequence of the application of heat. Salts, ſulphur, and metals, are the chief bodies ſubjected to this proceſs. Crucibles of baked clay of porcelain, of courſe grit of iron and platina, of various kinds and figures, with metallic cones or ingot moulds, are the inſtruments chiefly uſed. Theſe laſt give the figure to the matter, which, after being melted and cooled again, has the form of a bar, or ingot, or a button.

In reduction or revivification, the oxyds of metals are reſtored to their metallic ſtate by the aſſiſtance of fire, with charcoal or oils, or other inflammable matter.

Vitrification, is the fuſion of ſubſtances capable of aſſuming the brightneſs, tranſparency, hardneſs, and other properties of glaſs. Vitrifiable earths with alkalis, and metallic oxyds, are the principal matters ſubjected to this operation.

Cupellation is the purifying of perfect metals, and the extraction of the imperfect mixed with them, by means of an addition of lead. This laſt, promotes the vitrification of the imperfect metals, ſo that theſe laſt are carried off, and the perfect metals are left nearly pure. The name of this operation is taken from the veſſels made uſe of, which are a kind of flat crucibles, ſimilar to ſmall cups called cupels. Theſe are formed of the earth of bones, which, on account of its poroſity, eaſily imbibes the glaſs of lead.

Certain powders made uſe of for including particular bodies intended to be changed by their action, in cloſe veſſels, ſubjected to heat, are called cements. Thus it is that iron is cemented with powder of charcoal to convert it into ſteel; and glaſs with plaſter or ſand, to convert it into a kind of porcelain. Cementation is a proceſs, which, in certain caſes, requires a very ſtrong heat.

Stratification is an operation nearly ſimilar to the foregoing: It conſiſts in the arrangement of various ſolid bodies in a crucible, or other veſſel capable of reſiſting the fire. Theſe are generally in the form of bars or plates, and are blended with pulverable matters, capable of altering their nature. The form and the diſpoſition of theſe matters in beds or layers, *ſtrata ſuper ſtrata*, has given riſe to the name ſtratification. In this manner copper or ſilver are treated with ſulphur, in order to effect a combination. This proceſs differs from fuſion, calcination, or vitrification, only in the particular diſpoſition of the matters ſubjected to it.

Detonation is peculiar to nitre, and thoſe matters of which it is a component part. It conſiſts in the greater or leſs noiſe produced by the exploſion of theſe ſubſtances when heated, ſuddenly or ſlowly, and by degrees in open or cloſe veſſels. Decrepitation which differs from detonation in its noiſe being much leſs, and in the kind of crackling ſound with which it is accompanied, is peculiar to ſuch ſalts as burſt aſunder by heat, which cauſes their water of cryſtallization to expand, and make its eſcape. It is particularly obſerved in common ſalt or muriat of ſoda. Fulmination is a quick and ſudden detonation obſerved in fulminating gold, fulminating powder, and the combuſtion of inflammable and pure air, &c.

The operation of volatilizing by heat, ſuch ſubſtances as are in a dry, ſolid, and often cryſtalline ſtate, is called ſublimation. The ſublimatory veſſels are of glazed earthen ware, or earthen cucurbits, with glaſs heads, or pots of earthen ware, or porcelain, called aludels, matraſſes, &c. Sulphur, arſenic, cinnabar, and many mercurial preparations, ſome vegetable matters, and in particular, camphire and flowers of benzoin, are the chief ſubſtances which are raiſed in ſublimation.

Evaporation is the action of heat upon liquids, in order to diminiſh the fluidity and quantity of the reſiduum, and to obtain the fixed bodies it may hold in ſolution. In this way the water of the ſea or ſalt ſprings is driven off, and the ſalt is left. This operation is made in broad veſſels of earth, glaſs, ſilver, or other metals, according to the nature of the liquids under examination. Evaporation is performed by an open fire, or with acceſs of air, in order that the fluid intended to be driven off may be at liberty to expand and be diſſipated, and that this may be effected more quickly by virtue of the diſſolvent power of the air on fluids in a ſtate of vapour.

Diſtillation is an operation nearly of the ſame nature, but performed in cloſed veſſels. It is intended to ſeparate the volatile from the fixed principles, by means of heat. Diſtillatory veſſels are either alembics or retorts: The former conſiſts of an inferior veſſel, called a cucurbit, deſigned to contain the matter to be diſtilled, and having an upper part fitted to it, called the capital or head. In this laſt, the vapours are condenſed by the contact of the ſurrounding air, or in other caſes by the aſſiſtance of cold water ſurrounding the head, and contained in a veſſel, called a refrigiratory. From the lower part of the capital proceeds a tube, called the noſe, beak or ſpout, through which the vapours, after condenſation, are, by a proper figure of the capital, made to flow into a veſſel called the receiver, which is uſually ſpherical. Theſe receivers have different names, according to their figure, being called matraſſes, balloons, &c. Retorts are a kind of bottle of glaſs, pottery, or metal, of a conical figure, having its extremity bent ſo as to form an angle more or leſs acute with its body, and hence the name *retort*. Diſtillation is improperly diſtinguiſhed into three kinds, by aſcent *per aſcenſum*, by deſcent *per decenſum*, and ſideways *per latus*. Theſe diſtinctions, which are but futile, ſeem to have been taken from the form of the veſſels. Matter in a ſtate of vapour always tends to riſe, but diſtillation by alembics has been called per aſcenſum, becauſe the capital being immediately above the body, the vapours riſe in an obvious manner. The diſtillation by retorts has been called per latus, becauſe the neck of the retort comes out at the ſide of the apparatus, though the roof of the retort be higher than its neck, and though the vapours paſs over only after having been condenſed by the external cold in the roof, or higheſt part of the retort. As to the diſtillation per deſcenſum, it is an unſkilful and ill-contrived operation, which is no longer uſed, becauſe its products are for the moſt part loſt, and thoſe which are obtained are in a foul and imperfect ſtate. It was performed by placing ſome vegetable ſubſtance on a cloth extended over the mouth of a glaſs veſſel containing ſome water; on this was laid a metal diſh containing live coals. In this way cloves, and ſeveral odoriferous matters were in the ancient pharmacy, and for perfumer's uſe, diſtilled to obtain their eſſential oil. The product paſſed through the linen, and was condenſed by the water; but the greateſt part made its eſcape between the metallic diſh cover and the cloth. A diſtinction relating to the manner of heating bodies intended to be diſtilled, is much more neceſſary to be made, than thoſe we have been ſpeaking of. The water bath, the vapour bath, the ſand bath, the bath of aſhes, conſiſt of theſe ſubſtances contained in proper veſſels over the fire. In theſe the diſtallatory veſſels are plunged, and are by that means kept at a more determined and equal heat. The naked fire is alſo uſed in diſtillations, as is alſo the flame of a lamp, or of ſpirit of wine.

Rectification is a ſecond diſtillation, in which ſubſtances are purified by their moſt volatile parts being raiſed by heat carefully managed. Thus ſpirit of wine, ether, &c. are rectified by their ſeparation from the leſs volatile and foreign matter, which altered or debaſed their properties.

Concentration is the inverſe of rectification, as it is intended to deprive fixed fluids of the water which weakens them. This operation implies, it is evident, that the matter to be concentrated is heavier than water, and is uſed for certain acids, particularly the ſulphuric, phoſphoric, and alſo for ſolutions of alkaline and neutral ſalts.

Digeſtion is an operation in which ſuch matters, as are intended to act ſlowly on each other, are expoſed to a ſlow heat continued for a long time. It is particularly uſed in the extraction of ſuch parts from vegetables as are ſoluble in ſpirit of wine, or other fluids uſed for this purpoſe. The ancient chemiſts held this proceſs in great eſtimation. Though this confidence ſeems well founded, in conſideration of the change which, after ſtrict examination, it is found that moſt vegetable and animal ſubſtances undergo by a too powerful heat, yet it is not carried to that enthuſiaſm which the alchemiſts ſhowed in their purſuits. Theſe men, with more aſſiduity and labour than their pretended art deſerved, made digeſtions of many years duration, and believed by that means that it would be in their power to work a great number of miracles. Digeſtion is now confined to the preparing of tinctures, elixirs, cordials, and it is ſucceſsfully uſed in the extractions of vegetable or animal principles without alteration. It is likewiſe uſed to advantage in ſeveral proceſſes with minerals.

Infuſion is a proceſs well known. It conſiſts in pouring water of any required degree of temperature on ſuch ſubſtances as have a looſe texture, as thin bark, wood in ſhavings or ſmall pieces, leaves, flowers, &c. It is very uſeful in ſeparating the moſt ſoluble parts of theſe, and is applied in a great number of chemical operations.

Decoction, or continued ebullition with water, is employed to ſeparate ſuch parts of bodies as are only ſoluble at this degree of heat. It greatly alters vegetable and animal matters, coagulates the lymph, melts the fats and reſins, hardens fibrous parts; and is advantageouſly uſed in chemical operations, by ſuch as are acquainted with its effects.

Lixivation, is the operation of diſſolving or extracting, by the help of hot water, the ſaline and ſoluble matter contained in the aſhes of plants, or the reſidues of diſtillation, or combuſtion, or of coals, or natural earths intended to be analyſed. As by this operation, ſalts of the kind termed lixivial are generally obtained, it was natural to give it the name which it bears: The ſynonymous word *leſſive*, is, at preſent, more frequently uſed in France, than even the term lixiviation. This operation, therefore, is nothing more than a ſolution by the aſſiſtance of heat, and does not differ from infuſion, except in the particular application of the latter to vegetable and animal matters, while the former is applied to ſubſtances that have the properties of minerals.

Such are the different operations performed in chemiſtry, by the aſſiſtance of fire: And as nothing was formerly done without this agent, this ſcience was then no more than an art, and was called Pyrotechnia. At preſent it is much leſs uſed, in conſequence of the diſcovery of more certain methods of analyſing natural ſubſtances. The action of ſolvents or menſtruums employed without the application of any heat beyond the temperature of the air, is ſufficient to effect the moſt ſingular changes, and is productive of clear and valuable deductions. This method is purſued with ſucceſs in the examination of ſalts, earth, vegetable matters, &c. Heat is now regarded only as an auxiliary agent, by which combinations are forwarded. As it is employed in different degrees, it would be a valuable acquiſition, if we knew how to apply it with uniform intenſity. A furnace of this kind has long been a deſideratum among chemiſts, and the manipulations of artiſts have hitherto been the only guide to the chemiſt; but it is impoſſible by this means to have the degree of preciſion ſo much to be deſired. Dr. Black has contrived furnaces which appear proper to produce a regular and uniform heat, by means of regiſters, which are opened or cloſed at pleaſure. We have not received ſufficient information to enable us to conſtruct the like; but as the art of chemiſtry cannot but be greatly benefited by this diſcovery, it is to be hoped that it will be ſpeedily adopted in France *.

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* Dr. Black's furnace is deſcribed in the Edinburgh New Diſpenſatory, printed in the year 1786, p. 49, 50.

NOTES ON CHAPTER V.

[Page 139.]

[a] Fourcroy has neglected to explain the nomenclature of caloric. The following note is intended to ſupply this omiſſion.

1. The *caloric* of the French chemiſts is ſynonymous with the *igneous fluid* of Lavoiſier, with the *abſolute heat* of Dr. Crawford, and with the *matter of heat* of La Place. Theſe terms expreſs a particular kind of matter, or a particular quality of matter, which exiſts under a variety of modifications that are mutually convertible.

2. One of theſe modifications is *free* caloric. It is in this ſtate that caloric affects animals with the ſenſation of heat, and that it expands in every direction the bodies into which it enters. *Free* caloric was formerly called *ſenſible heat*, and is ſynonymous with the expreſſions of *interpoſed* caloric, *uncombined* caloric, *thermometrical fire*, and caloric of *temperature*.

3. Regarding caloric, as an eminently elaſtic fluid, which is always tending to expand, according to certain laws peculiar to itſelf, it is ſaid that caloric tends conſtantly to the ſtate of *equilibrium*. It is upon this property of caloric, that the uſe of thermometers is founded. When a mercurial thermometer is immerſed in water, the caloric of the water makes an effort to diffuſe itſelf through the mercury, and the caloric of the mercury makes an effort to diffuſe itſelf through the

water. If the tendencies to expand be equal in theſe two quantities of caloric, both quantities will remain at reſt; the mercury will neither be expanded by the entrance of caloric from the water, nor will it be contracted by the loſs of any part of its own caloric. But when the tendencies to expanſion are unequal, the caloric is impelled from the ſubſtance where it had exiſted in the ſtate of the greateſt *tenſion*, into the ſubſtance where it had exiſted in the ſtate of the leaſt tenſion; and this flow of caloric continues till the forces expanding it are in equilibrium. When this happens, the degree of dilatation of the mercury, or other fluid employed in the conſtruction of the thermometer, is ſaid to indicate the *temperature* of the ſubſtance to which it is applied.

4. Caloric is conſtantly tending to the ſtate of equilibrium, but it paſſes with different degrees of facility through different bodies. It paſſes, for example, with greater facility through metals, than through wood or glaſs. Bodies are, therefore, ſaid to be more or leſs *permeable* to caloric, or to *conduct* caloric more or leſs readily.

5. When equal quanties of water, at different temperatures, or of any other homogeneous ſubſtance ſuited for ſuch experiments, are mixed together, the caloric flows from the quantity which has the higheſt temperature, and diffuſes itſelf through the quantity which has the loweſt temperature, till the forces expanding it are in equilibrium, in every part of the maſs; and it is then found that the temperature of the maſs is the arithmetical mean between the temperatures of the two quantities that had been originally mixed together.

6. When equal quantities of two different ſubſtances are taken, and mixed together at different temperatures, the caloric, as in the former caſe, flows from the body which has the higheſt temperature, and diffuſes itſelf through the body which has the loweſt temperature, till the expanding forces are in equilibrium, and conſequently till both ſubſtances have acquired the ſame temperature; but the temperature of the mixture is no longer, as in the former caſe, the arithmetical mean between the temperatures of the two ſubſtances that had been originally taken. In every known inſtance, it deviates from that mean, approaching more or leſs to the temperature of one of the ſubſtances employed. An example will illuſtrate this fact, and the concluſion to be deduced from it. When a pound of ice, at 32°, is mixed with a pound of the white oxyd of antimony by nitre (diaphoretic antimony), at 27°, the uniform temperature of the mixture is 31°; the ice having loſt 1° of temperature, and the oxyd of antimony having gained 4°. Now, the oxyd of antimony receiving preciſely as much caloric in this experiment, as is taken from the ice, it follows, that the ſame quantity of caloric, which is capable of raiſing the temperature of the oxyd of antimony 4°, is capable of raiſing the temperature of the ice only 1°, ſince the abſtraction of it has reduced the temperature of the ice only 1°. This fact is expreſſed by ſaying, that the *capacity* of the white oxyd of antimony for caloric, is to the *capacity* of ice for caloric, as 1 is to 4. That is, the *capacities* of bodies for caloric expreſs the relative quantities of caloric, which are neceſſary to raiſe the temperature of equal quantities of theſe bodies the ſame number of degrees, provided the bodies do not change their *ſtate* or *form*, while this increaſe of temperature takes place [*]. Lavoiſier and La Place have employed the language of *ſpecific heat*, to expreſs the ſame idea [†].

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[*] Bodies, it is neceſſary to obſerve, exiſt in three different *ſtates* or *forms*; that of ſolidity, that of liquidity, and that of elaſtic fluidity.

[†] The objections which ſome authors have made to the uſe of the term *capacity for caloric*, diſappear before the preceding definition of that expreſſion, taken from

7. There are two methods of determining the capacities of bodies for caloric. The one conſiſts in mixing together equal quantities of different bodies at different temperatures, and obſerving the temperature of the mixture as ſoon as it becomes uniform. The capacities of the bodies are in this caſe inverſely, as the changes of temperature. The other method conſiſts in raiſing the temperature of different bodies to the ſame degree, encloſing equal quantities of them ſeparately in a ſphere of ice, and collecting the quantity of water which is obtained from the thawing of the internal ſurface of the ice, while the body placed within it is cooled down to the temperature of 32°. The capacities in this caſe are directly as the quantities of ice melted. The firſt of theſe methods has been practiſed by Dr. Crawford. The ſecond was contrived by Lavoiſier and La Place. The principles of both methods are explained with ſingular perſpicuity and accuracy, by theſe two celebrated academicians, in their valuable *Memoire ſur la Chaleur*, publiſhed in the volume of the Memoires of the Royal Academy of Sciences at Paris, for 1780. The ſame paper contains directions for reducing the ſecond method to practice; and directions for the firſt are given by Dr. Crawford, in his Treatiſe on Animal Heat, and by Seguin, in the fifth volume of the *Annales de Chimie.*

8. The *ſpecific* caloric of the French chemiſts expreſſes the relative quantities of caloric contained in equal weights of different bodies, reduced to the ſame temperature; or it means the whole quantity of caloric contained in a body, compared with the whole quantity contained in another body, having the ſame weight, and the ſame temperature. Dr. Crawford has uſed the term *comparative heat*, in the ſame ſenſe.

9. It is ſtill a queſtion among chemiſts, whether the whole quantities of caloric contained in equal weights of different bodies, having the ſame temperature, be proportioned to the capacities of theſe bodies? It has been aſcertained, that in many chemical changes, caloric diſappears, is abſorbed, or becomes *latent;* while, in the converſe of theſe changes, preciſely the ſame quantity of caloric reappears, is evolved, becomes *free* or *ſenſible.* Thus, when a pound of ice at 32°, is mixed with a pound of water at 167°, the ice is liquefied, but the temperature of the mixture continues at 32°; that is, ice abſorbs as much caloric in thawing, as would raiſe the temperature of an equal quantity of water 135°. In the ſame manner, when water at 212°, is converted into ſteam, the ſteam abſorbs as much caloric without having its temperature increaſed by it, as would raiſe the temperature of an equal quantity of water 943°, if the water were not convertible, at that temperature, into ſteam. But the capacity of ſteam for caloric, is greater than the

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Seguin. M. Pictet propoſes to retain the expreſſion of *ſpecific heat*, which was introduced by Lavoiſier and La Place, in the ſenſe in which Seguin has defined capacity. But this language is in itſelf objectionable, and is apt to be confounded with the term *ſpecific caloric*, which has a very different meaning. It is to be obſerved, that Dr. Crawford's definition of capacity is either inapplicable to any property of bodies which we are able to meaſure at preſent, or involves an inadmiſſible hypotheſis; and is therefore to be rejected. He defines the capacity of a body, to be that power in the body by which it collects and retains the *abſolute heat*; that is, the whole caloric of the body (page 7 and 8). But it is a mere hypotheſis, that the whole caloric of a body is proportioned to that property of the body which is meaſured in Dr. Crawford's experiments.

M. de Luc's definition of *capacity* differs both from that of Seguin and that of Dr. Crawford. Tranſlating his peculiar language on the ſubject into that of the French chemiſts, we ſhould ſay that he underſtands, by the different *capacities* of bodies, the unequal quantities of caloric contained in equal ſpaces, or in equal volumes of different ſubſtances, having the ſame temperature, (Idees ſur la Meteorologie, tom. 1. § 154, 162, 167).

capacity of water, and the capacity of water is greater than the capacity of ice. Conſequently, more caloric will be neceſſary, to give water the temperature of 32°, than to give ice the temperature of 32°; and more will be required to give ſteam the temperature of 212°, than to give water the temperature of 212°. It may then be queſtioned, whether the whole caloric that diſappears in the melting of ice, and in the converſion of water into ſteam, has been abſorbed by the water and ſteam reſpectively, in conſequence of their change of capacity? Or, whether ſome part of it has not been chemically united with the water and ſteam reſpectively, in ſuch a manner as not to affect their temperatures? Dr. Crawford inclined to the former of theſe hypotheſes; the French chemiſts are diſpoſed to admit the latter.

10. It is principally with the view of determining whether the ſpecific caloric of bodies be proportioned to their capacities, that the inquiry after the *real zero*, or *point of total privation*, has been purſued. It is taken for granted, in this inquiry, that whenever caloric is abſorbed or evolved by a ſyſtem of bodies, the quantity abſorbed or evolved, has the ſame ratio to the whole caloric exiſting in the ſyſtem after the experiment is concluded, which the difference between the former and preſent capacity of the ſyſtem has to its preſent capacity. An example will illuſtrate the manner in which the real zero is calculated from theſe principles. When ice is converted into water, its capacity is increaſed in the ratio of 9 to 10, according to Kirwan; and as much caloric is abſorbed, according to La Place, as would be ſufficient to raiſe the temperature of water 135°. Let us ſuppoſe that the whole of this abſorption depends on the change of capacity in the ice; it will follow, that 1-10th of the whole caloric contained in water at 32°, is ſufficient to maintain the temperature of the water 135°; and, conſequently, the remaining 9-10ths will be able to maintain its temperature, $135 \times 9^{\circ} = 1215^{\circ}$. That is, the whole caloric contained in water at 32°, is ſufficient to communicate the temperature of 1350° to a body, having the ſame capacity with water; and therefore the abſolute zero, or point of total privation, as determined by this calculation, is 1328° below 0 of Fahrenheit's ſcale.

When we conſider the expanſive power of caloric, and its conſequent tendency to the ſtate of equilibrium, it is evident that the real zero, or point of total privation, muſt be the ſame in bodies of every kind; and the preceding calculation will therefore conduct us, in every inſtance, to the ſame point, provided the principles on which it is founded are juſt, and provided the neceſſary experiments have been made with accuracy.

It is in this view, that the inquiry after the real zero, ſerves to aſcertain whether the hypotheſis be true, that the ſpecific caloric of bodies is proportioned to their capacities. For, if different experiments ſhall, without exception, indicate the ſame point, as the abſolute zero, it may be inferred that the hypotheſis in queſtion is juſt; and, on the contrary, if the concluſions from different experiments ſhall diſagree, and if their differences be greater than what may be reaſonably allowed for, on account of the difficulty of conducting experiments of ſo great nicety, it may be inferred, that the ſpecific caloric of bodies is not proportioned to their capacities; that the abſorption and evolution of caloric, in different proceſſes, depend not entirely upon the changes of capacity in the ſubſtances employed, but, in ſome meaſure, on the entrance of caloric into chemical combination.

The experiments that have been hitherto made, to aſcertain the real zero, are not ſufficiently numerous, nor ſufficiently free from objections, to authoriſe either of the preceding concluſions, though they are infinitely more favourable to the latter than to the former. Seguin has given a ſhort account of them in the 5th volume of the Annales de Chimie. Dr. Crawford has related his own experiments and thoſe of M. Gadolin, and has given a mathematical demonſtration of the principle on which the inquiry is founded. La Place has given, as uſual, a very elegant and perſpicuous view of the queſtion. See Crawford on *Animal Heat*, and the *Memoire ſur la Chaleur, par Lavoiſier et La Place*, in the volume of the Memoirs of the Academy of Sciences for 1780.

11. Dr. Crawford has publiſhed, in the Appendix to his Treatiſe on Animal Heat, a table of the *comparative heats* of different ſubſtances. This table is conſtructed on the ſuppoſition that the comparative heat, or ſpecific caloric of a body, is proportioned to its capacity. But that ſuppoſition being gratuitous, not to ſay improbable, Dr. Crawford's table of comparative heats, is nothing more than a table of capacities; and in that view, it is a valuable addition to the ſcience of caloric.

12. The facts curſorily ſtated in 9, illuſtrate the doctrine of *latent* heat; and as much caloric being evolved during the condenſation of ſteam, and the congelation of water, as diſappears during the formation of ſteam, and the melting of ice, the principle laid down by La Place, and referred to by Fourcroy, in an after part of the text, is confirmed by them; but the hypotheſis of *combined caloric*, derives its plauſibility from a variety of ſources. It is impoſſible, in a ſketch of this kind, which is intended merely to explain the nomenclature of caloric, to give that ſyſtematic view of the ſubject, which its difficulty, and its importance demand. A reference is therefore made to ſome of the moſt valuable works that relate to the theory of *combined* caloric. Theſe are, the different *Memoires* by Lavoiſier, publiſhed in the *Memoires de l'Academie Royale des Sciences*, particularly one *De la Combinaiſon de la Matiere des feu avec les Fluides Evaporables, et de la Formation des Fluides Elaſtiques Aeriformes, et une Memoire ſur le Combuſtion en General*, both publiſhed in the volume for 1777; *Reflexions ſur le Phlogiſtique*, in the volume for 1783; *Une Memoire ſur la Chaleur, par Lavoiſier et La Place*, in the volume for 1780; *Elemens de Chimie, par Lavoiſier*, tranſlated by Kerr; *Methode de Nomenclature Chymique, par M. M. Morveau*, &c. tranſlated by Dr. Pearſon; *Les Obſervations des Chimiſtes François, ſur l'Eſſai de M. Kirwan, ſur le Phlogiſtique*, tranſlated by Nicholſon; Dr. Crawford's work on *Animal Heat*; two eſſays by Seguin, *Sur la Calorique*, publiſhed in the 3d and 5th volumes of the *Annales de Chimie*; the firſt part of M. Pictet's *Eſſai ſur le Feu*; part of the article *Air*, in the chemical parts of the new *French Encyclopedia*, by the celebrated Guiton, *cidevant de* Morveau; ſome obſervations which Berthollet has introduced into his excellent work, *Sur la Teinture*, tranſlated by Dr. Hamilton; the article *Feu*, in De Luc's *Idees ſur la Meteorologie*; *Diſſertations on Different Subjects in Natural Philoſophy*, and a *Diſſertation on the Philoſophy of Light, Heat, and Fire*, by Dr. Hutton of Edinburgh.

b An obſervation made by M. Humboldt might lead to uſeful inquiries on the ſubject of etiolation. He found that ſeveral of the claſs cryptogamia, ſuch as the *lichen verticellatus*, puſh out green ſtalks, though placed in mines, where the light has no acceſs to them; and that ſeveral of the gramina, the *poa annua* and *trefolium arvenſe* in particular, have green leaves, when growing in the galleries of certain mines, at the depth of 60 toiſes below the ſurface of the earth. Examining the air in theſe ſituations, he found that it was mingled with hydrogenous gas. (Journal de Phyſique for 1792.) It would ſeem, from this caſual obſervation, that the preſence of hydrogenous gas compenſates, to a certain extent, in vegetation, for the abſence of light. M. Ingenhouſz has alſo remarked, that when hydrogenous gas is mingled with the air in which vegetables grow, the verdure of the latter acquires a much deeper ſhade.

M. Humboldt mentions, in a ſubſequent letter to M. Crell, that he has had frequent opportunities of confirming the truth of the obſervations related in his former letter, and that he had diſcovered another ſpecies of lichen in the mines at Marienburg, which had ramifications of a bright green colour. He had alſo found, that the *cheiranthus incanus*, and *cheiranthus cheiri*, placed in certain circumſtances, puſh out green leaves, without the preſence of light. He imputes theſe ſingular phenomena to the hydrogenous gas uniting with the exceſs of oxygen, which he ſuppoſes to be preſent in etiolated plants, and to be the immediate cauſe of their etiolation. (Journal de Phyſique, Part 2d, for 1793.)

[c] So far from caloric adding to the weight of bodies, it would appear, from an experiment very accurately related by Dr. Fordyce, that caloric diminiſhes the weight of the bodies into which it enters, as *latent* caloric. It was found in this experiment, that 1700 grains of water acquired by freezing the additional weight of very nearly 1-16th part of a grain. The water and ice were both weighed at the temperature of 32°. (Philoſophical Tranſactions, 2d Part, for 1785). This experiment has been confirmed, in a very ſatisfactory manner, by Sir Benjamin Thompſon. Water was counterpoiſed with ſpirit of wine, and the apparatus was then placed in a low temperature, where the water was frozen, while the ſpirit of wine remained liquid. The water, as in Dr. Fordyce's experiment, became heavier, in conſequence of its converſion into ice.

It is proper at the ſame time to ſtate, that in a ſimilar experiment, Lavoiſier found no difference between the weight of the ice and water. The quantity of water which he made uſe of in this experiment was one pound, and it weighed preciſely as much before as it did after it was frozen. The balance he employed was ſenſible to the difference of 1-10th of a grain, when loaded with 18 or 20 ounces. (Memoires de l'Academie de Sciences, 1783, page 419.)

An attempt has been lately made by Dr. Higgins, to aſcertain whether the caloric emitted during the ſlaking of lime produces any ſenſible difference in the weight of the materials employed; but the experiment failed. (Minutes of the Society for Philoſophical Experiments and Converſations, page 220.)

[d] Since *latent* caloric appears, from Dr. Fordyce's experiment, to diminiſh the gravity of bodies, there is reaſon to inquire whether free caloric has not a greater tendency to aſcend than to deſcend. M. Pictet has made ſeveral experiments to aſcertain this point. A cylindrical bar of copper was placed vertically within a glaſs tube, which was afterwards exhauſted of air, by means of the air-pump. The concentrated rays of the ſun were thrown upon the middle of the cylinder and the ſucceſſive dilatations of two mercurial thermometers, connected with its two extremities, were carefully obſerved. It was found, that, in the ſame times the mercury in the upper thermometer roſe to a greater height than in the under one; and, after the light was withdrawn, the under thermometer ſunk faſter than the upper one. *Eſſai ſur le Feu*, chap. 2d.

[e] M. Pictet has publiſhed ſome experiments on the caloric produced by friction.

He had imagined that the caloric evolved by friction was obtained from a mechanical decompoſition of the air between the rubbing ſurfaces; but he found that the ſame degree of friction raiſed the thermometer ſomewhat higher in vacuo than in the open air. This difference was no doubt occaſioned by the greater conducting power and greater capacity of the air than of the vacuum; but ſtil the experiment ſhowed that his firſt conjecture had been unfounded. In his ſubſequent experiments, it appeared that more caloric was evolved by the friction of ſoft bodies againſt his friction-machine than when hard bodies were employed; and the friction of a ſmall quantity of cotton upon the bulb of his thermometer, increaſes the effect moſt remarkably. (Eſſai ſur le Feu, chapitre 9ieme).

f The diffuſion of caloric among a ſyſtem of bodies ſeems to depend on two cauſes; on their reſpective capacities for caloric, and on their reſpective conducting powers. M. Pictet has illuſtrated the manner in which theſe cauſes co-operate, with ſingular perſpicuity. It is impoſſible to place the ſubject in a clearer point of view than by a free tranſlation from his work.

Let us ſuppoſe a focus, from which flows a conſtant and uniform ſtream of caloric; and let us place at equal diſtances from this focus and connected with it by the ſame medium, a number of bodies, having the ſame nature, and the ſame magnitude. Theſe bodies will be filled with caloric in the ſame manner, their temperatures will riſe by ſimilar gradations, and will ceaſe to riſe, when the caloric they contain ſhall have acquired an expanſive power ſufficient to reſiſt the introduction of more caloric from the focus. But let us place at equal diſtances from the ſame focus, a number of bodies, having the ſame weight, and differing in their nature, ſuch as a pound of water, a pound of glaſs, a pound of mercury, &c. Theſe bodies will be filled with caloric as the former bodies were, and they will arrive at length at the ſame common temperature, but in different times, and by diſſimilar gradations. This difference will depend on the combination of two cauſes. The one is, the different *permeability* of the bodies to caloric, or their different *conducting* powers, in conſequence of which caloric will take a longer or ſhorter time to penetrate their ſubſtance. The other is, the different capacities of the bodies for caloric, in conſequence of which they will require unequal quantities of *free* caloric to arrive at the ſame common temperature; that is, to the ſtate in which the free caloric of the whole ſyſtem of bodies tends to expand itſelf with the ſame force.

I. We have little accurate information reſpecting the *permeability* of bodies to caloric. We owe to Dr. Franklin the obſervation, that the non-conductors of electricity are alſo bad conductors of caloric, and that the beſt conductors of electricity are alſo excellent conductors of caloric. We have examples of this analogy between the electric fluid and caloric, in metals upon the one hand, and in glaſs and reſinous ſubſtances on the other. But this rule is liable to many exceptions. The common torricellian vacuum affords a ready paſſage to the electric fluid; but Sir B. Thompſon found, that it was leſs permeable to caloric than atmoſpheric air, which itſelf is a very bad conductor of caloric. Sulphur and oils, which are non-conductors of electricity, are repreſented by Humboldt as among the beſt conductors of caloric.

In order to conſtruct a table of the permeability of bodies to caloric, it would be neceſſary to know the times during which equal weights of different bodies acquire the ſame increaſe of temperature, when expoſed to equal calorific cauſes, or ſuſtain the ſame loſs of temperature, when expoſed to equal cooling cauſes. It would be alſo neceſſary to know the capacities of the bodies for caloric. The conducting powers would be directly as the capacities, and inverſely as the times, when the changes of temperature were equal. But in the attempts that have been hitherto made to calculate the permeability of bodies to caloric, the conſideration of their capacities has been uniformly neglected; and in many of Sir B. Thompſon's experiments, unequal weights of different ſubſtances were uſed, and no attention afterwards paid to this difference in calculating the conducting powers. He makes, for example, the conducting power of mercury : conducting power of water : : 1000 : 313; but in the experiments from which this eſtimate is taken, he had uſed equal volumes of the water and mercury, and conſequently had communicated the ſame increaſe of temperature to more than 13 times as much matter in the one experiment as in the other.

The following table of the conducting powers of different ſubſtances is taken from the *Journal de Phyſique*, for October 1793. It is there given as the tranſlation from the German of an eſſay by Humboldt, on the Conducting Powers of different Bodies for Caloric. From the ſhort account prefixed to it in the Journal de Phyſique, it would appear to be defective in this reſpect, that the conducting powers of the ſubſtances which it contains have been calculated without regard to the differences of their capacities; but as it is the lateſt and moſt comprehenſive table of the kind, it has been thought the moſt proper for inſertion. It is neceſſary to mention, that the conducting powers given in the table refer to the ſame volumes, and not to the ſame weights of the ſubſtances enumerated.

TABLE OF CONDUCTING POWERS.

Conducting Media.	*Specific Gravities.*	*Conducting Powers.*	*Authorities.*
Torricellian vacuum		0.1760	Sir B. Thompſon. (*Phil.*
Atmoſpheric air, denſity = 1	0.0012	0.2550	The ſame. [*Tranſ.* 1786.)
Rarefied air, denſity = 1-24th		0.2490	The ſame.
Wood aſhes	1.5560	0.7072	Humboldt.
Sulphuric acid	1.7000	0.7764	
Ruſt of iron	4.5000	0.8889	
Copper	8.5760	0.8970	Richmann. (*Comment. Acad.*
Iron	7.8076	0.9430	*Petropol.* 1752.)
Braſs	8.3960	0.9430	
Cow's milk	1.0300	0.9727	Humboldt.
Vinegar	1.0110	0.9900	Mayer. (*On the Laws and*
Water	1.0000	1.0000	*Modifications of Caloric.*)
Gold	19.0400	1.0504	Humboldt.
Moiſt air		1.0543	Thompſon.
Nitrous acid	1.5800	1.0989	Humboldt.
Silver	10.0010	1.2195	
Muriatic acid	1.1500	1.2787	
Calcareous earth	2.8570	1.3674	
Olive oil	0.9130	1.5472	
Tin	7.2910	1.5410	Richmann.
Zinc	6.8620	1.5455	Humboldt.
Oxyd of lead	8.9400	1.6474	
Antimony	6.8600	1.6952	
Alcohol	0.8150	2.0379	
Lintſeed oil	0.9280	2.0412	
Pitcoal	1.5000	2.4003	Humboldt.
Mercury	13.5800	1.9700	Mayer.
Lead	11.4459	0.3138	Richmann.
Biſmuth	9.8610	2.3584	Humboldt.
Eſſence of turpentine	0.7920	2.6752	

Conducting Media.	*Specific Gravities.*	*Conducting Powers.*	*Authorities.*
Sulphur	1.8000	3.0358	Humboldt.
Ice	0.9160	1.2130	
* Mercury	13.5800	3.1948	Thompſon.

II. The *capacities* of bodies for caloric have been ſuccefsfully inveſtigated by a variety of chemiſts. The following table exhibits the principal concluſions reſulting from theſe experiments. But it is neceſſary, in the firſt place, to explain what is meant by the *permanence* of the capacities of bodies for caloric.

The capacity of a body for caloric is ſaid to be *permanent*, while the ſame quantity of caloric that has raiſed its temperature any given number of degrees, continues to be ſufficient to raiſe its temperature an equal number of degrees. The capacity of a body for caloric is ſaid, on the contrary, to increaſe, when more caloric is required to raiſe it a certain number of degrees than was required to raiſe it an equal number of degrees, when it had a different temperature; and the capacity is ſaid to decreaſe, when leſs caloric is required for that purpoſe. Dr. Crawford has made a variety of experiments on this ſubject. He found that the capacity of water is permanent from the freezing to the boiling point; and afterwards, making uſe of water as a ſtandard, he tried ſimilar experiments with moſt of the metals and metallic oxyds. The general reſult of theſe experiments tended to prove, that the capacities of bodies, while they retain the ſame *form*, are not liable to be varied by a change of temperature. This concluſion is corroborated by the uniformity of the law which bodies obſerve in parting with caloric, when they are placed in a temperature inferior to their own. This law, firſt inveſtigated by Sir Iſaac Newton, and ſince corrected and tried experimentally by Martine and Muſſchenbrock, ſhows, from its application to the cooling of different bodies, that the capacities of theſe bodies are either permanent, or, if they change, that the changes are preciſely ſimilar in all of them.

But theſe experiments embrace only a ſmall number of natural bodies; and Dr. Crawford's in particular were neceſſarily confined to a mere point in the ſcale of temperature. It is, therefore, departing from the ſtrictneſs of induction to conclude, as Dr. Crawford has done (p. 65.), that the capacities of *all* bodies are permanent at *all* temperatures, provided they do not change their form. We have, indeed, the moſt complete proof that this principle is not to be received without many limitations. The capacity of air is increaſed by mechanically expanding it, and diminiſhed by mechanically condenſing it. (Pictet *ſur le Feu*, § 16. and Darwin's Frigoric Experiments on the Mechanical Expanſion of Air, *Philoſophical Tranſactions* for 1788.) Mr. Wedgwood's clay thermometer has its capacity for caloric diminiſhed one-third, when burnt to 120° of his ſcale; and as it loſes in weight, during this operation, little more than two grains on a pound, while its volume is reduced one-half, the diminution of capacity muſt be attributed to its condenſation. Theſe facts prove deciſively that the capacity of a body may be changed without any change of form; and the free caloric evolved from ſo many bodies by friction and attrition, while its production is illuſtrated by theſe obſervations, ſerves at the ſame time to multiply the examples of a change in the capacity of bodies without a change in their form. (Mr. J. Wedgwood's Paper on the Light produced by Attrition, Philoſophical Tranſactions for 1792.) It is proper to mention, that Lavoiſier and La Place, in their *Memoires ſur les Chaleur*, had called in queſtion, upon very plauſible grounds, the ſuppoſed permanence of the capacities. Reaſoning from the known effects of fuſion and evaporation upon the capacities, they ſuggeſted, as extremely probable, that the capacities would alſo vary with the degree of dilatation, and poſſibly according to a different law for every different body. Subſequent obſervations ſeem to juſtify their conjecture with reſpect to many bodies at leaſt.

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* This eſtimate of the conducting power of mercury is not in Humboldt's table, but is calculated from Sir B. Thompſon's experiments. It is unneceſſary to point out how much it differs from Mayer's eſtimate.

TABLE OF CAPACITIES.

		Authorities.
Hydrogen gas	21.4000	Crawford.
Oxygen gas	4.7490	
Atmoſpheric air	1.7900	
Steam or aqueous vapour	1.5500	
Carbonic acid gas	1.0454	
Arterial blood	1.0300	
Water	1.0000	
Cows milk	.9999	
Venous blood	.8928	
Azotic gas	.7936	
Hide of an ox with the hair	.7870	
Lungs of a ſheep	.7690	
Muſcular fleſh of an ox	.7400	
Alcohol	.6021	
Rice	.5060	
Horſe beans	.5020	
Spermaceti oil	.5000	
Fruit of the pine tree	.5000	
Peaſe	.4920	
Wheat	.4770	
Barley	.4210	
Oats	.4160	
Sulphuric acid	.4290	
Pitcoal	.2771	
Charcoal	.2631	
Chalk	.2564	
Ruſt of iron	.2500	
Waſhed diaphoretic antimony	.2272	
Oxyd of copper nearly freed from air	.2272	
Quicklime	.2229	
Cinders	.1923	
Aſhes of pitcoal	.1855	
Ruſt of iron nearly freed from air	.1666	
Waſhed diaphoretic antimony do.	.1666	
Aſhes of elm wood	.1402	
Oxyd of zinc nearly freed from air	.1369	
Iron	.1269	
Braſs	.1123	
Copper	.1111	
White oxyd of tin almoſt free of air	.0990	
Zinc	.0943	

		Authorities.
Zinc	.0943	
Aſhes of charcoal	.0909	Crawford.
Tin	.0704	
Yellow oxyd of lead almoſt free of air	.0680	
Antimony	.0645	
Lead	.0352	
Snow	.9000	Magellan.
Ice	.9160	Humboldt.
Bar-iron	.1099	Lavoiſier and
Rock-cryſtal	.1929	La Place.
Mercury	.0290	
Quicklime	.2168	
Mixture of 9 parts of water with 16 of quicklime	.4391	
Sulphuric acid, having the ſp. gr. of 1.87	.3345	
Mixture of 4 parts of this acid with 3 parts of water	.6031	
Mixture of 4 parts of the ſame acid with 5 of water	.6631	
Nitric acid, having the ſp. gr. of 1.29895	.6613	
Mixture of $9\frac{1}{3}$ of this acid with 1 of quicklime	.6189	
Mixture of 1 part of the nitrat of potaſh with 8 parts of water	.8167	
Sulphur	.1830	Kirwan.
Lintſeed oil	.5280	
Cryſtallized muriat of ſoda	.226	Gadolin.
Saturated ſolution of muriat of ſoda in water (containing 372 parts of the ſalt to 1000 parts of water)	.793	

§ Dr. Hutton of Edinburgh, has lately pointed out a new principle in the action of light, conſidered as a power influencing the temperature of bodies; and has applied this principle to the explanation of various phenomena, (Diſſertation on the Philoſophy of Light, Heat, and Fire, 1794). The following is a ſhort abſtract of his ſpeculations upon that ſubject.

1. He obſerves, that the efficacy of the different ſpecies of light, in raiſing the temperature of bodies, is not proportioned to their action upon the ſenſe of viſion. The influence of the red light, from a fire of coals, and of the white light, from flame, upon the thermometer, were compared together, when the intenſity of their action upon the organ of ſight, was apparently the ſame, it was found that the effect of the red light upon the inſtrument, was incomparably greater than that of the white light.

2. When bodies are heated to incandeſcence, they emit light, in which the white or compound ſpecies prevails; but, as their temperature diminiſhes, the light gradually becomes of the red ſpecies. It would appear, from this obſervation, that the light emitted from bodies, while they paſs from the ſtate of incandeſcence, to the common temperature of the atmoſphere, has its power of exciting viſion diminiſhed in a greater ratio, than its power of influencing temperature.

3. When the light emitted from a body, ceaſes to be viſible, we are not to conclude that the body ceaſes to radiate light. The fact proves no more, but that the light radiated, is unable to excite our ſenſe of viſion. This light emitted from bodies, without affecting ſenſibly the organ of ſight, is called by Dr. Hutton, *obſcure* or *inviſible* light.

4. We have ſeen that the light emitted from bodies, as they paſs from the ſtate

of incandeſcence to the common temperature of the atmoſphere, has its power of exciting viſion diminiſhed in a grater ratio, than its power of influencing temperature. It may therefore happen, that our obſcure or inviſible light ſhall ſtill retain the power of ſenſibly influencing temperature; and this ſuſpicion will be confirmed, if we find that a ſubſtance exhibiting the diſtinctive properties of light is radiated from a body of elevated temperature, but not luminous; and if we find that this radiated ſubſtance is capable of raiſing the thermometer. But this is preciſely what happens in the experiments made by Sauſſure and Pictet. Two concave mirrors are placed oppoſite to one another, at the diſtance of many feet, the bulb of a thermometer is in the focus of the one, and a glaſs matraſs, filled with boiling water, or an iron bullet, heated ſo as to be juſt not viſible in the dark, is placed in the focus of the other. A ſubſtance is radiated from the matraſs or iron bullet; it paſſes with incalculable velocity through the air; is reflected from the mirrors, and concentrated according to the laws of light, and then influences the thermometer placed in the focus, according to the degree of its concentration.

5. It is ſuppoſed by Sauſſure and Pictet, that the ſubſtance radiated in theſe experiments, is not any ſpecies of light, but what Lambert and Sauſſure calls *chaleur obſcure;* that is, caloric unaccompanied with light *. But the properties of this radiation, its velocity and reflexibility, identify it with light, while they are inconſiſtent with the ſlow diffuſion of caloric, and with the known diſpoſition of caloric to be arreſted by the bodies through which it paſſes, or with which it comes into contact. An experiment made by M. Pictet, § 54, ſerves to confirm this reaſoning. He blackened the bulb of his thermometer, and found that it was then more ſpeedily influenced by the radiation than before, and that it roſe to a greater height. But it is notorious, that black ſurfaces abſorb light more powerfully than white ſurfaces do, and have their temperature more conſiderably affected by it.

6. It may be urged, in objection to this concluſion, that if we ſuppoſe the thermometer dilated by the reflected and concentrated light, why ſhould not that light be rendered viſible by the concentration? Dr. Hutton conceives that, ſince the peculiar efficacy of this light, in affecting the temperature of bodies, muſt depend on its greater aptitude to combine with them, this ſame diſpoſition for combination, will diſqualify it from appearing as light. At the ſame time, he leaves to experimentaliſts to determine how far this ſpecies of light, after having once diſappeared to our ſenſes, is incapable of becoming again viſible; unleſs the temperature of the body with which it has combined, be raiſed to the degree of incandeſcence, in which caſe it may poſſibly be emitted from the body, as viſible light.

7. Taking it for granted that the emanation which affects the thermometer in theſe experiments, is inviſible light; we learn, from the ſame experiments, compared with others made by Marriotte and Scheele, that this inviſible ſpecies of light is much abſorbed in paſſing through a glaſs lens, while it is but little diminiſhed, in being reflected by a metallic ſurface.

8. Dr. Hutton afterwards proceeds to analyſe Mr. Pictet's curious experiment of apparently reflected cold; Pictet ſur le Feu, § 69, 71.; Hutton's Philoſophy of Light, &c. page 67, 100. It will be unneceſſary to abridge this part of his

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* Dr. Hutton affects to conſider the expreſſion of *chaleur obſcure*, as either unintelligible, or manifeſtly inapplicable to the emanation in queſtion; but it is plain that Sauſſure underſtands by that term, caloric unaccompanied with light, in contradiſtinction to *chaleur lumineuſe*, caloric accompanied with light.

work; for, although his obſervations on the phenomena of that ſingular experiment appear to be exceedingly juſt, and his doubts reſpecting the courſe of the radiation to be founded on the moſt ſolid grounds, yet he has left the ſubject in a ſtate of confeſſed uncertainty; having merely pointed it out, without having performed any of the experiments neceſſary for its elucidation.

9. In the courſe of his obſervations on this experiment, he is led to propoſe an hypotheſis reſpecting inviſible light, with the account of which we ſhall conclude the preſent article. He ſuppoſes that bodies are conſtantly radiating inviſible light, in proportion to their temperatures; and that this inviſible light falling upon other bodies, raiſes their temperature, or is reflected by them, according to their reſpective natures. At the ſame time, the ſenſible heat of bodies (the free caloric) is always tending to equilibrium, according to the laws of its diffuſion, and in conſequence of the mechanical operation of the elaſtic fluids conveying it from place to place. From the combination of theſe cauſes, the temperature of bodies is always tending, on the one hand, to equality; and this perfect equality is, on the other hand, prevented from actually taking place, by the different diſpoſitions of bodies to abſorb inviſible light, and to have their temperatures affected by it. Dr. Hutton applied this theory to explain M. Pictet's experiment, and at the ſame time ſuggeſts an experiment, by which he conceives the truth of his own theory may be confirmed, or its fallacy diſcovered. It may be worth while to add, that M. Prevoſt of Geneva, has publiſhed ſome ſpeculations, extremely analogous, in many reſpects, to Dr. Hutton's views upon this ſubject; with this difference, that what Dr. Hutton calls inviſible light, M. Prevoſt, conformably to Sauſſure's opinion, terms *chaleur rayonnante*. Recherches Phyſico-Mechaniques ſur la Chaleur, 1792.

h It is impoſſible for chemiſts, in the preſent ſtate of their ſcience, to decide, whether the light emitted during combuſtion, be derived *principally* from the combuſtible body, or from the oxygenous gas? For it ſeems improper to derive it excluſively from either, when there is reaſon to believe that it enters into the compoſition of both.

It muſt be confeſſed, indeed, that the evidence for light being a conſtituent part of oxygenous gas, is far from being unexceptionable. The principal argument is taken from the ſingular influence of light, in ſeparating oxygen from its combinations, and making it aſſume the ſtate of oxygenous gas. Light diſengages oxygenous gas from the nitric acid, from the oxygenated muriatic acid, and from the oxyds of ſeveral metals. But in theſe, and many ſimilar inſtances, does the light combine with the oxygenous gas? Or, does it unite with the ſubſtance from which the oxygen is ſeparated? There is no fact in chemiſtry that will enable us to decide between theſe two hypotheſes; and thoſe chemiſts who, with Fourcroy, regard light and caloric as two ſubſtances eſſentially different, have abſolutely no reaſon for inclining to the one hypotheſis, in preference to the other.

The exiſtence of light, as a conſtituent part of combuſtible bodies, is proved in the moſt ſatisfactory manner, by the experiments of Deiman, Pacts, Van Trootſwyck, &c.; Recherches Phyſico-Chymiques. Theſe chemiſts expoſed a mixture of ſulphur and zinc to a high temperature, without any ſubſtance being preſent, from which they could derive oxygen. At the inſtant when the ſulphur and zinc formed a *ſulphure*, there was a vivid emiſſion of light; and when the materials were afterwards examined, it was found that no oxydation had taken place. This experiment ſucceeds with other metals, beſides zinc; ſuch as copper, tin, lead, and faintly with iron. It has been tried with equal ſucceſs *in vacuo*, above mercury, and in hydrogenous, azotic, and carbonic acid gaſes.

It has been for a long time a deſideratum in chemiſtry, to poſſeſs a method of meaſuring the quantity of light emitted from bodies in the ſtate of combination. Count Rumford has publiſhed in the Philoſophical Tranſactions for 1794, the deſcription of a very ſimple inſtrument, which he has contrived for this purpoſe. The following are the principal reſults of his experiments with this inſtrument, or *photometer.*

The tranſparency of air is ſo great, that the diminution which light ſuffers in paſſing through 16 or 18 feet of air, is not perceptible with this inſtrument.

Somewhat leſs than 2-10ths of a beam of light are loſt in paſſing through a pane of fine, clear, tranſparent, well poliſhed glaſs, ſuch as is commonly made uſe of in the conſtruction of looking glaſſes; ſomewhat more than 3-10ths are loſt in paſſing through two panes of ſuch glaſs; and about 12-100ths, in paſſing through a pane of thin colourleſs window glaſs. The light fell perpendicularly upon the glaſs in theſe experiments; but the loſs was very little greater in oblique incidences, provided the angle of incidence did not exceed 40° or 50°.

Somewhat more than 1-3d of a beam of light was loſt by reflection from a very excellent glaſs mirror; and about 46-100ths, from a common looking glaſs. The angle of incidence was 45°, and the reſult was not ſenſibly affected by increaſing the angle to 85°.

Count Rumford has collected, in the following table, the reſults of his experiments on combuſtion. It is to be obſerved that each of the undermentioned articles is ſuppoſed to afford the ſame quantity of light; the table denoting how much of each muſt be employed for that purpoſe.

		Equal parts in weight.
Bees wax.	A good wax candle, kept well ſnuffed, and burning with a clear bright flame, - -	100
Tallow.	A good tallow candle, kept well ſnuffed, and burning with a bright flame, - -	101
	The ſame tallow candle, burning very dim, for want of ſnuffing, - - -	229
Olive oil.	Burned in Argand's lamp, - -	110
	The ſame burned in a common lamp, with a clear bright flame, without ſmoke, - -	129
Rape oil.	Burned in the ſame manner, - -	125
Lintſeed oil.	Likewiſe burned in the ſame manner, - -	100

Count Rumford concludes his Paper with an account of ſome experiments on the tranſparency of flame; from which it appears that light ſuſtains no ſenſible diminution, in conſequence of paſſing ſucceſſively through the flames of ſeveral candles.

[i] Fourcroy is not correct in ſaying that all mineral ſubſtances are dilated by caloric. The minerals that contain a large proportion of aluminous earth, afford a ſtriking exception to the general rule. The phenomena which attend the expoſure of theſe ſubſtances to intenſe fires, are deſcribed minutely by Mr. Wedgwood. Philoſophical Tranſactions, Part II. for 1786.

[k] The conſtruction of Muſſchenbrock's pyrometer is deſcribed in his *Tranſlation of the Experiments of the Academy del Cimento*, Leyden, 1731, and in Deſagulier's *Experimental Philoſophy*, vol. I. p. 421; and a pyrometer of a new conſtruction,

by which the expanſion of metals, in boiling liquids, may be examined and compared with Fahrenheit's thermometers, is deſcribed in *Muſſchenb. Introd. ad Philoſoph. Natural.* 4to, 1762, vol. 2. p. 610.

Mr. Ellicott's improved pyrometer is deſcribed in the *Philoſophical Tranſactions*, No. 443; Mr. Smeaton's pyrometer, in the 48th volume; De Luc's, in the 68th volume; and Mr. Ramſden's, in the 65th volume, p. 461, of the ſame works. Mr. Ferguſon has alſo contrived a pyrometer, which is deſcribed in the Supplement to his *Lectures on Mechanics.*

[l] The diminution of temperature produced by evaporation, had been obſerved by Mairan (*Diſſertation ſur la Glace*, edition of 1749), and accurately deſcribed by Richmann (*Nova Comm. Acad. Petropolit.* ad ann. 1747 and 1748, page 284); but was firſt referred to its proper cauſe by Dr. Cullen, Eſſay on the Cold produced by evaporating Fluids.

In the 78th volume of the Philoſophical Tranſactions, Dr. Darwin has related ſeveral experiments, to prove that a diminution of temperature takes place when the air is mechanically expanded; and converſely, that the temperature riſes when the air is condenſed. He has applied this doctrine with great ingenuity to explain a variety of curious phenomena. Dr. Cullen had obſerved that a thermometer ſuſpended in the receiver of an air pump, ſinks always two or three degrees, while the air is exhauſted.

[m] The attention of chemiſts was for ſome time drawn from the hypotheſis of Macquer to the very ingenious defence of the doctrine of phlogiſton by Mr. Kirwan. According to this philoſopher, phlogiſton, or the inflammable principle, may exiſt in two different ſtates; 1ſt, Combined, as in all bodies ſuſceptible of combuſtion. 2dly, Free and iſolated, as in inflammable air. Beſides the evolution of light and heat, combuſtion, therefore, is ſuppoſed to conſiſt in the union of this inflammable principle with oxygenous gas, and in the conſequent generation of carbonic acid. A full account of this hypotheſis, which the author has ſince ſo candidly retracted, may be ſeen in the laſt edition of Kirwan's Eſſay on Phlogiſton, a work which, in addition to the original matter of the author, contains ſome very intereſting notes by M. M. Morveau, Lavoiſier, De la Place, Monge, Berthollet, and Fourcroy.

The hypotheſis of Macquer has of late been revived with ſome ſlight alterations by Richter, Gren, Lichtenberg, and others in Germany. Phlogiſton, or the inflammable principle, according to the firſt of theſe chemiſts, is merely the baſis of light united to combuſtible bodies. In combuſtion, this baſis is diſengaged, and, uniting with a portion of caloric, produces the light or flame which uſually accompanies that proceſs. The combuſtion of any inflammable ſubſtance, phoſphorus for inſtance, is, therefore, to be conſidered as the effect of a double affinity. The baſe of the oxygenous gas, unites with the phoſphorus to form phoſphoric acid, while a portion of the caloric, diſengaged from this gas, unites with the phlogiſton, or baſis of light, to produce flame.

The varieties which occur in the quantity of light emitted by different bodies, and in the colours which it exhibits, are ſuppoſed to depend on the quantity of phlogiſton contained in theſe bodies, and on the proportions in which it is united to caloric. See *Critique des Antiphlogiſchen Syſtemes von J. B. Richter*, S. 48. Breſslau, 1793. *Syſtematiches Handbuck des Chemie von F. A. C. Gren. Erſt. Th. S.* 172. Halle, 1794.

Dr. Hutton of Edinburgh has publiſhed a new modification of the phlogiſtic doctrine, together with ſeveral objections to the French theory of combuſtion.

The following is a ſhort enumeration of his principal concluſions upon theſe ſubjects.

1. The caloric, which becomes free by combuſtion, did not previouſly exiſt as latent caloric, either in the oxygenous gas conſumed, or in the combuſtible body.

2. The immediate effect of combuſtion is the diſengagement of light, and this light produces free caloric, by its action, in the bodies upon which it is incident. To uſe Dr. Hutton's own language, "it is not heat which is the cauſe of light in "fire, but it is the light of fire which is then the cauſe of heat."

3. The light which is diſengaged during combuſtion, previouſly exiſted in the burning body in the ſtate of phlogiſton. This phlogiſton is a peculiar modification of the ſolar ſubſtance, exiſting in combuſtible bodies, and diſtinct from any modification of heat. It neither adds to the weight of bodies, nor does it ſeem, like latent caloric, to impair their weight. It communicates ductility and ſplendor to the metals. It is ſeparated from its union with gravitating matter during combuſtion, and appears in the form of light. It is formed in plants during the proceſs of vegetation, and may be transferred from one body to another. See *Diſſertations on Different Subjects in Natural Philoſophy*, and *Diſſertation upon the Philoſophy of Light, Heat, and Fire*, by James Hutton, M. D.

It would be an endleſs, as well as uſeleſs taſk, to enumerate all the different modifications of phlogiſton which have been propoſed by the partizans of that doctrine, ſince Lavoiſier firſt ventured to queſtion its exiſtence. Thoſe readers who will take the trouble to peruſe all the different writings on this controverſy, will immediately perceive that no two chemiſts are agreed with regard to the preciſe nature and properties of this principle, and that it is merely for the name, and not for the thing, that phlogiſtians now ſo eagerly and ſo obſtinately contend.

It would be eaſy to illuſtrate the truth of this remark, by a reference to the writings of Prieſtley, Kirwan, Wiegleb, La Methrie, Macquer, Richter, Gren, Hutton, &c.; but this reference is unneceſſary. Stahl is univerſally allowed to have been ignorant of the principal phenomenon that occurs in every inſtance of combuſtion; and does it not ſeem ſtrange, that we ſhould adhere tenaciouſly to the theory which he invented to explain that proceſs, that we ſhould ſtill continue to uſe the language of a ſyſtem now ſo avowedly defective?

The theory of Lavoiſier, if we may give to it that name, is merely a ſimple relation of facts. Unable to diſcover the ſource from which the light is derived in combuſtion, that philoſopher, in his Elements of Chemiſtry, has taken care not to mix any hypotheſis concerning it, with the facts he had fully aſcertained by experiment. Whether future diſcoveries ſhall ſhow, that heat and light are modifications of the ſame ſubſtance, or that they are eſſentially different from each other; whether the whole of the light diſengaged in combuſtion, ſhall be found to come from the oxygenous gas, or from the combuſtible body, or partly from both, the theory of combuſtion, as eſtabliſhed by Lavoiſier, will remain unalterably the ſame. Diſcoveries with regard to the origin and nature of light, can only tend to widen and to ſtrengthen its baſis.

[n] Rock-cryſtal is not quite ſo refractory in the fire, as repreſented by Fourcroy. Lavoiſier placed a ſmall piece of it within red hot charcoal, and expoſed it to a ſtream of oxygenous gas. The rock-cryſtal crackled and ſplit, its angles were a little blunted, and it had ſome appearance of ſoftening. After it cooled, it was found to have loſt its tranſparency, in conſequence of the ſeparation of its laminæ, by the force of the fire. Mem. de l'Acad. 1783, page 566. Profeſſor Errhmann has ſince fuſed rock-cryſtal by a flame, urged with a ſtream of oxygenous gas. Nicholſon's Dictionary of Chemiſtry, page 278.

[o] Theſe aſſertions are proved by experiments, the particulars of which are to be found in a variety of works: in the 1ſt volume of de Luc's *Idees ſur la Météorologie*, and in his *Recherches ſur les Modifications de l'Atmoſphere*; in the Memoire of Lavoiſier and La Place, *Sur la Chaleur*; in Seguin's Obſervations on Caloric, publiſhed in the 3d volume of the *Annales de Chimie*; in Crawford's Treatiſe on Animal Heat; in the *Acta Suecica* for 1772; in Magellan's Eſſay on Fire; in M. Pictet's *Eſſai ſur le Feu*, &c. &c.

[p] In the proſecution of theſe and many ſimilar objects of inquiry, it is neceſſary for chemiſts to have it in their power to produce very low degrees of temperature. This may be done by frigorific proceſſes, during the warmeſt weather of ſummer. An account is given in the Philoſophical Tranſactions for 1787, 1788, and 1789, of ſome very economical, and, at the ſame time, very powerful frigorific mixtures.

[q] This ſeems the proper place for obſerving, that the mercurial thermometer is an accurate meaſure of temperature. It is found that the dilatations and condenſations of the mercury with which it is filled, are *very nearly* proportional to the caloric which it receives, or which is taken from it. This fact was aſcertained by M. de Luc, and his experiments have been repeated with great care, by Dr. Crawford; and ſimilar reſults obtained, or rather reſults more favoarable than De Luc's, to the juſtneſs of the mercurial thermometer, as a meaſure of temperature. See Crawford's Treatiſe on Animal Heat, page 18—53.

Martine has given directions for the conſtruction and graduation of thermometers. See Eſſays. Conſult, for the ſame purpoſe, the Philoſophical Tranſactions of London, volumes 66th and 67th; De Luc's Recherches ſur les Modifications de l'Atmoſphere, and Nicholſon's Dictionary of Chemiſtry.

Martine may alſo be conſulted for a comparative table of the different ſcales, according to which thermometers had been conſtructed previous to his time. Fahrenheit's ſcale is generally uſed in Britain, Reaumur's in France. One degree of Fahrenheit's ſcale = 4-9ths of a degree of Reaumur's, = 5-9ths of a degree of Celſius.

[r] Mr. Wedgwood's clay pyrometer is deſcribed in the 72d volume of the Philoſophical Tranſactions, and additional obſervations on its conſtruction and uſe are contained in the 74th and 76th volumes of the ſame collection.

The following is Mr. Wedgwood's table of the changes experienced by various ſubſtances, at different degrees of temperature, expreſſed according to his own, and to Fahrenheit's ſcale.

	Wedgwood's Scale.	*Fahrenheit's Scale.*
Extremity of the ſcale of Wedgwood's pyrometer, - -	240°	32277°
Higheſt temperature of his ſmall air-furnace, about 8 inches ſquare, -	160	21877
Caſt iron melts, - -	130	17977
Higheſt temperature of a common ſmith's forge, - -	125	17327
Welding temperature of iron, greateſt,	95	13427
———————— leaſt,	90	12777
Fine gold melts, - -	32	5237
Fine ſilver melts, - -	28	4717
Swediſh copper melts, -	27	4587
Braſs melts, - -	21	3807

	Wedgwood's Scale.	*Fahrenheit's Scale.*
Temperature at which Mr. Wedgwood's enamelled colours are burned on,	6°	1857°
Red heat fully viſible in day light,	0	1077
Red heat fully viſible in the dark,	—1	947
Mercury boils,	—3.673	600
Water boils,	—6.658	212
Medium temperature of man,	—7.542	97
Water freezes,	— 8.42	32
Proof ſpirit freezes,	—8.289	0
Mercury freezes, about	—8.596	—40

Mr. Nicholſon, in his Dictionary of Chemiſtry, has given a very full abſtract of the two firſt of Mr. Wedgwood's Papers.

CHAPTER VI.

CONCERNING ATMOSPHERICAL AIR.

COMMON air is an inviſible, inodorous, inſipid, gravitating, elaſtic fluid, eaſily put in motion, capable of rarefaction and condenſation, which ſurrounds our globe to a certain height, and is called the atmoſphere. It penetrates and fills up the interſtices or pores which exiſt among the integrant particles of bodies. The atmoſphere is far from being entirely compoſed of pure air. As it receives all kinds of vapours that riſe from the earth, it may be conſidered as a chaos, whoſe parts are very difficult to be known. We ſhall ſee, however, that this inquiry has been proſecuted with conſiderable ſucceſs. Water, mineral exhalations, and the elaſtic fluids diſengaged from vegetables and metals, are continually riſing into the atmoſphere, and conſtitute, as it were, its different elements. The hiſtory of the atmoſphere conſiſts of that of its height, which is not yet aſcertained with preciſion; of the changes it experiences in weight; of its ſeveral ſtrata; of the effects of its rarefaction and dilatation; of winds, and of meteors. All theſe objects belong to that part of natural philoſophy which is called meteorology, and does not come within our intended limits: But as the air has a ſingular influence on all chemical phenomena, and it cannot but be of conſequence to know in what reſpects this is exerted, we ſhall here pay ſome attention to its phyſical, as well as its chemical properties.

§ 1. *Concerning the Phyſical Properties of Common Air.*

We regard the fluidity, its inviſibility or extreme tranſparency, its want of taſte or ſmell, its gravity and its elaſticity, as the phyſical properties of air. Each of theſe requires to be attended to ſeparately.

The rarity of the air is ſuch, that it eaſily yields to the ſmalleſt impulſe, and is diſplaced by the ſmalleſt motion of bodies immerſed in it. The rarity and fluidity depend on its peculiar ſtate of aggregation; and as the ſame ſtate is found in other ſubſtances not of the ſame nature as the air of the atmoſphere, ſuch ſubſtances are termed aeriform fluids or gaſes. It is the diſtinguiſhing criterion of this ſtate of aggregation, that bodies poſſeſſing it do not aſſume the ſolid ſtate by mere cold, as moſt liquid ſubſtances do; that is to ſay, we are unacquainted with the preſſure or degree of refrigeration capable of rendering them ſolid; and this is the character of permanent gaſes. The fluidity of the air renders it ſuſceptible of thoſe frequent and rapid motions of its parts, which are called winds. It is not, however, of that ſubtlety, as to paſs through the pores of many bodies. Tranſparent ſubſtances, through which light paſſes with extreme facility, are not penetrable by air. Water, ſaline ſolutions, oils, and ſpirit of wine, paſs through a great number of bodies, whoſe texture is not penetrable by air *. It has not that property by which liquids inſinuate themſelves into the pores of certain bodies, and cauſe them to expand.

Air included in veſſels is perfectly inviſible. It is not at all diſtinguiſhable from the glaſs which contains it, and though it fills the veſſel completely, it exhibits to the eye the appearance of a vacuum. Its tenuity, and the great facility with which it ſuffers the rays of light to paſs through its ſubſtance, are the cauſe of this; it refracts the light without reflecting it. It is conſequently colourleſs, though ſome philoſophers have thought its large maſſes were blue †[a].

The air has always been ſuppoſed to be perfectly inſipid. But if we attend to the conſequences of this fluid touching any bare nerve of an animal, as is the caſe in wounds and other ſimilar circumſtances, we may conclude that it has a kind of ſapidity which habit has probably rendered inſenſible. In fact, the expoſure of wounds to the air is often attended with very acute pain[b]. The infant, at the inſtant of its birth, ſufficiently ſhows, by its cries, the diſagreeable impreſſion this contact occaſions. This kind of acrimony in the air appears to be the cauſe of that difficulty with which wounds cicatrize, if not kept covered; at-

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* This may be true; but it has never been proved in the moſt ſatisfactory manner; namely by the condenſer. T.

† Colourleſs fluids appear to reflect the light in the order of its reflexibility, and will therefore appear of a different tinge, accordingly as they are viewed by reflected or tranſmitted light. Thus the air is either red, orange, or yellow, according to its thickneſs, as is ſeen by the colour of the clouds illuminated at ſunſet by this tranſmitted light; the green, blue, indigo, and violet rays being more reflexible, are turned back, and exhibit the ſky blue. Water has a ſimilar appearance when in large maſſes. The ſea, by reflection, is blue, but by tranſmiſſion is red, as Halley obſerved in the diving bell. T.

moſpherical air alſo prevents cicatrization in vegetables which have been deprived of their bark; and the reproduction of this membrane is known to take place only when the external air is excluded.

The air is perfectly inodorous, and in thoſe caſes, in which a ſort of fetid ſmell is perceived, it is eaſily accounted for, by attention to the foreign bodies interſperſed through it, as miſts, or vapours *.

The weight of the air is one of the moſt valuable diſcoveries in natural philoſophy. It was not well eſtabliſhed till about the middle of laſt century, though it is affirmed, that Ariſtotle knew that † a bladder is heavier when full of air, than when empty. The ancients had no idea of the weight of the air; but attributed all the phenomena ariſing from that weight to an occult quality they called the horror of a vacuum. The impoſſibility of raiſing water by the common pump to a greater height than thirty-two feet, engaged certain workmen to conſult the famous Galileo, who was greatly ſurpriſed at the fact. Death, in all probability, prevented his ſagacity from diſcovering the true cauſe of this, which was reſerved for his diſciple Torricellius. He was led to it by the following reaſoning: The water appeared to him to riſe in the ſucking pump ſolely in conſequence of an exterior cauſe, which, by preſſure, obliged it to follow the piſton. The action of this cauſe is evidently limited, as appears by its ſuſtaining a column of no more than thirty-two feet of water. If, therefore, it were to act on a fluid ſpecifically heavier than water, it ought to raiſe and ſuſtain to a height inverſely as its ſpecific gravity. From theſe reflections he was induced to take a tube of glaſs hermetically ſealed at one end, and thirty-ſix inches in length. He filled this with mercury, the cloſed end being downwards; then cloſing the extremity with his finger, he raiſed the other end uppermoſt, and plunged the unſealed end beneath the ſurface of a veſſel of mercury. Upon removing his finger, he obſerved the mercurial column to deſcend, till after ſeveral oſcillations its upper ſurface remained at twenty-eight inches above the ſurface of

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* The ſmell of electricity is often perceived by ſedentary people, when they go into the open air. T.

† It is not eaſy to conjecture what may have occaſioned Boyle's miſtake in repeating this experiment. He found the bladder lighter when empty than when blown up. This certainly cannot be; for the air in the bladder, acting only by its reſidual gravity in air (which is nothing) could not cauſe any preponderance.

the mercury in the baſon. By comparing this height with the height of thirty-two feet, to which water is raiſed in pumps, he found it correſponded accurately to the inverſe ratio of the weights. For the ſpecific gravity of mercury and water being in round numbers, as 14 to 1, the mercury was found to ſtand in the vacuum at only one fourteenth of the height of the water. It was not till after much meditation, that he ſuſpected the weight of the air to be the cauſe of the ſuſpenſion of water in pumps; and this doctrine was not incontrovertibly eſtabliſhed in France, till after the ingenious experiment of Paſcal in that kingdom.

This celebrated philoſopher imagined, that if water were ſuſtained at the height of thirty-two feet in pumps, and mercury at twenty-eight inches in the Torricellian tube, by the ſole gravity of the air, the heights of theſe fluids ought to vary with that gravity; that they ought not, for example, to be the ſame on the top of a mountain and in a valley, becauſe the length of a column of the atmoſphere muſt be ſhorter, and conſequently its weight leſs in the former than in the latter caſe. In purſuance of this idea of Paſcal, M. Perrier on the 19th of September, 1648, at the foot and at the ſumit of the mountain Puits de Dome in Auvergne, made the famous experiment, which has for ever fixed the opinion of philoſophers on this ſubject. The barometer, or Torricellian tube filled with mercury, and fixed to a ſcale of thirty-four inches, divided into inches and lines, ſhowed a fall or diminution of the mercurial column equal to four inches, in aſcending from the foot of the mountain to its ſummit, which is five hundred toiſes higher. By this it was aſcertained, that the mercury varies about an inch for every hundred fathoms; and this inſtrument has ſince that time been very ſucceſsfully applied to meaſure the height of mountains.

The weight of the air has great influence on a number of phyſical and chemical phenomena. It compreſſes all bodies, and oppoſes their dilatation. It is an obſtacle to the evaporation of fluids. The water of the ſea is by this cauſe preſerved in its liquid ſtate, without which it would take the vaporous form, as we ſee in the vacuum of the air pump. The preſſure of the air on our bodies preſerves the ſtate both of the ſolids and fluids; and from the want of this due preſſure it is, that on the ſummits of lofty mountains the blood often iſſues from the pores of the ſkin, or from the lungs, and occaſions hemorrhages.

Laſtly, the air is ſtrongly elaſtic. It is capable of being very much condenſed, and ſuddenly regains its former ſtate when at liberty. A great number of facts prove the truth of this aſſertion. We ſhall here mention one or two of the moſt obvious and concluſive. If mercury be poured into a tube in the form of the letter U, and cloſed at one end, the air in the cloſed end will contract in its dimenſions, in proportion as the quantity of mercury by which it is compreſſed is greater. The foot-ball of children, conſiſting of a bladder filled with wind, and encloſed in leather, ſhows the ſame claſticity, by its rebounding when it falls on hard bodies. The fountain by compreſſed air ſhows the ſame thing. This is a veſſel half filled with water, and air is ſtrongly compreſſed into its ſuperior part: The reaction of the air on the water forces it out to a conſiderable height through a tube. Laſtly, the wind gun, whoſe effects are well known, owes thoſe effects to the ſame property. It is eſtimated that air may be compreſſed into the 128th of its uſual volume.

Heat producing a contrary effect to that of compreſſion upon air, ſerves to ſhow, that its volume may be exceedingly augmented by the increaſe of its ſpring. When a bladder full of air is expoſed to the heat of a furnace, the air is dilated ſo as to burſt the bladder with an exploſion. This phenomenon is partly the occaſion of the burſting of chemical veſſels, which often happens where due precautions are not taken to prevent it. The abſence of the preſſure of the atmoſphere, or the total abſtraction of the circumambient air from beneath the receiver of an air pump, cauſes a bladder encloſed therein to burſt by the ſpring of the included air, which then acts without oppoſition.

From this account of the gravity and the elaſticity of the air, it may be readily inferred, that theſe properties are the leading cauſes of the numerous atmoſpherical changes, and the variations in the mercurial column in the barometer. In fact, the inferior ſtrata of the atmoſphere muſt ſuſtain the weight of the air above them, and are therefore in a ſtate of compreſſion, which diminiſhes with the greater elevation of places: And the continual change of temperature muſt alſo greatly affect the gravity of the air, by augmenting or diminiſhing its elaſticity. Thus, as we have already noticed, the air is lighter, keener, and more agitated on the tops of mountains than in lower regions; and it is only from the conſideration of the combined effects of the heat, gravity, and elaſticity of the atmoſphere, that the barometrical changes can be accounted for. M. de Luc, and M. de Sauſſure have paid great attention to this important ſubject for ſome years paſt *.

§ 2. *Concerning the Chemical Properties of Common Air.*

The properties we have deſcribed were formerly the only ones known, or treated of by philoſophers. But certain chemiſts, at the head of whom we may place Van Helmont, Boyle, and Hales, having perceived that air, or at leaſt a fluid poſſeſſing all its apparent properties, was obtained in the analyſis of many natural ſubſtances, adopted the opinion that this element combines with, and becomes fixed in bodies. Such is the origin of the term fixed air, which was given to the elaſtic fluids obtained in chemical operations. The early philoſophers ſuppoſed theſe fluids to be air; but the diſcoveries of Dr. Prieſtley have ſhown, that there are many bodies which have the phyſical properties of air, though they differ from it eſſentialy in many reſpects. It is, therefore, neceſſary to attend to thoſe other properties, in order to diſtinguiſh air from other aeriform fluids, which reſemble it in inviſibility and elaſticity. Theſe properties are chemical.

On inquiring into the characters of air, we find two which are peculiar to it, and well adapted to diſtinguiſh it from other elaſtic fluids. The one is the property of promoting the combuſtion or inflammation of bodies ſuſceptible of that proceſs; and the other is that of maintaining the life of animals that reſpire it. Let us carefully examine theſe important phenomena.

It is very difficult to give a good definition of combuſtion. It is a collection of phenomena, which certain bodies exhibit when heated with acceſs of air; the principle of which are the continuance or augmentation of heat, agitation, or inteſtine motion, the emiſſion of light, flame, redneſs, and a total change of the matter burned. Great differences may be obſerved in combuſtible bodies; ſome burn briſkly with a luminous flame, as oils, wood, reſins, bitumens; others burn without ſenſible flame, as many of the metals, and charcoal, if well made; others again are conſumed ſlowly without ſenſible ignition, though with heat, as is ſeen in certain metallic matters. In all theſe caſes the combuſtion is performed; and the body, thus burned, cannot be again ſubjected to the ſame proceſs. The reſidue of the combuſtion is always heavier than the body itſelf was before it was burned, as is more particularly ſeen in ſuch as are fixed in the fire: But ſuch bodies, as contain volatile inflammable matter, burn with more rapidity than the former, and leave a reſidue much leſs heavy than before. Oils, &c. are of this kind. But this diſtinction reſpecting the weight of the reſidue, is only apparent; for the reſidue in fact is in all caſes heavier than the body itſelf originally was. This important truth is evinced by a proper attention to the entire product of the inflammation. The fixed part of a body is not the whole reſidue ſtrictly conſidered, for the volatile parts eſcape into the air; and in ſome bodies the whole eſcapes in this manner. Theſe laſt would ſeem to be annihilated, if we were not to bring the volatile parts into our account, which is an abſurd poſition not to be maintained by inference from any phenomena. Thus we find that ſpirits of wine and ether burn without leaving any reſidue in the veſſels that contained them; but the matter they conſiſted of is volatilized and diſperſed. But if proper means be uſed to collect the product, it is found that its weight is greater than that of the original fluid. In this manner, M. Lavoiſier obtained eighteen ounces of water, by burning ſixteen ounces of pure and highly rectified ſpirit of wine, under a chimney adapted to the worm-pipe of a ſtill *. And the ſame phenomenon takes place with oils, reſins, &c. So likewiſe it is not to be concluded that the aſhes of wood is the true reſidue of the combuſtion. For a part of this ſubſtance is diſſipated in the air; that which is imperfectly burned, conſtituting ſoot; while another part eſcaping into the air is condenſed in the form of water, or exiſts in the form of elaſtic fluids of various kinds. It may, therefore, be taken for a general truth in chemiſtry, that the weight of bodies is increaſed by combuſtion.

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* The barometrical meaſurement of elevations has been well treated of, both practically and ſcientifically, by Sir George Shuckburgh and Colonel Roy in the 77th vol. of the Philoſophical Tranſactions. T.

The explanation of this increaſe of weight depends entirely on another phenomenon of combuſtion, which muſt be more mi-

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* Memoires de l' Academie Royale des Sciences pour l' Ann. 1781, page 942. *T.*

nutely inquired into. Combuſtion cannot take place without the acceſs of air, and is always carried on in proportion to the quantity and the purity of that fluid. This abſolute neceſſity for the preſence of air in combuſtion, has ſtruck philoſophers, ſince the time of Boyle and Hales; and each of them has propoſed his opinion on this ſubject. Boerhaave thought that the action of air conſiſted in its being applied to the ſurface of bodies, and in ſeparating the particles ſucceſſively from each other. This hypotheſis does not by any means ſhow why the ſame air ſhould not eternally ſerve to maintain combuſtion. M. Morveau ſuppoſed this laſt fact to depend on the too great rarefaction the parts of the air ſuffered by heat, in conſequence of which he imagined the combuſtible body might ſuffer a compreſſion incompatible with the ſtate of combuſtion. But this ingenious explanation was offered at a time when the true cauſe was entirely unknown. M. Lavoiſier, by his valuable experiments on the calcination of metals in known and determinate quantities of air, has proved the fact obſerved long ago by the naturaliſt John Ray, that a portion of the air is abſorbed during calcination; that the metal acquires as much weight as the air loſes; and that the metallic calx really contains this portion of air, as is ſhown by its diſengagement when mercury is reduced by the mere application of heat*. Other facts have carried him ſtill farther. With Prieſtley he has obſerved, that the air which remains after calcination and combuſtion, cannot be made to ſerve for new proceſſes of the ſame kind, but that it extinguiſhes bodies on fire, ſuffocates animals, and, in a word, it is no longer true air, &c.; and that the diminution is in proportion to † the quantity of air abſorbed by the combuſtible body. On the other hand, the air obtained from metallic calces, is found to be three or four times as pure as that of the atmoſphere ‡; ſince it is not only capable of maintaining combuſtion, but renders it much more rapid and perfect than ordinary air does; and a given quantity of this air will ſuffice to the perfect combuſtion of three or four times the quantity of a like body, which would be conſumed in an equal portion of atmoſpheric air. This ſingular fluid, which is obtained from mercurial calces has been called dephlogiſticated air, by its diſcoverer Dr. Prieſtley, who ſuppoſed it to be a portion of the air of the atmoſphere, from which the phlogiſton (which according to him always exiſts in the air) had been taken away and abſorbed by the calx of mercury, which is reduced in proportion as this elaſtic fluid is diſengaged by heat. But as this denomination may convey a falſe idea of the nature of this elaſtic fluid, we ſhall adopt the name of vital air, becauſe it is the only fluid which ſerves to maintain combuſtion or reſpiration, and becauſe it is, to uſe an expreſſion of M. Lavoiſier, air in a much more eminent degree than air itſelf.

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* Mem. de l'Acad. des Sciences, pour l'Ann. 1774 et 1775, p. 520. *T.*

† Mem. de l'Acad. des Sciences, pour l'Ann. 1776, p. 679 et pour l'Ann. 1777, p. 65, 188 et 201. *T.*

‡ Mem. de l'Acad. des Sciences, pour l'Ann. 1775. p. 525. *T.*

From the conſideration of the abſolute neceſſity of air to maintain combuſtion and its preſence in metallic calces, M. Lavoiſier concluded at firſt that combuſtion conſiſts in nothing more than the abſorption of pure air by the inflammable body. He regarded the air of the atmoſphere, abſtracting the water and different vapours that float therein, as a compound of two elaſtic fluids of a very different nature. The one, which is the only and true air, capable of maintaining combuſtion, by being precipitated on, and uniting with combuſtible bodies, is the pure or vital air. It compoſes from a fourth to a third part of the atmoſphere. The other, which is a fluid deſtructive to animal life, and extinguiſhes fire, conſtitutes from two-thirds to three-fourths of the atmoſphere, and was at firſt called by him atmoſpheric mephitis. When a combuſtible body is ſet on fire in contact with atmoſpherical air, the portion of vital air becomes fixed in the body, and the combuſtion continues while this proceſs is going on; but as ſoon as the whole of the vital air is abſorbed, it ceaſes. The reſidue, thus deprived of one of its conſtituent parts, cannot ſerve to maintain new combuſtions; but this atmoſpheric mephitis will regain the properties it had before, if a portion of pure air obtained from a metallic calx, or from nitre, be added in the ſame quantity as was loſt by combuſtion. This ingenious theory propoſed in 1776 and 1777, by M. Lavoiſier, ſeemed to explain all the phenomena of combuſtion. It clearly accounted for the increaſe of weight in metallic calces, and the extinction of combuſtible bodies in an air already employed in maintaining combuſtion; but M. Lavoiſier has thought it neceſſary to modify it by the addition of new obſervations ſuggeſted by his numerous experiments. The very bright flame obſerved when bodies in combuſtion are either plunged in vital air, or when it is blown in a ſtream on the ſurface of a body already on fire, by the help of an ingenious apparatus * that philoſopher has contrived for the purpoſe, induced him to inquire into its cauſe, and whether it might not be cauſed by the diſengagement of phlogiſton in the form of fire at liberty, according to the theory of Stahl. His attention to this inquiry was the more fixed by the conſideration that the celebrated Macquer, notwithſtanding the new diſcoveries, had not abandoned the theory of Stahl, but had connected his own theory with that of the father of chemical philoſophy. We have ſhown, that Macquer maintained the opinion, that the fixation of pure air in combuſtible bodies was performed only in proportion as phlogiſton was diſengaged; according to him, pure air and phlogiſton mutually precipitate each other in every inſtance of combuſtion; the phlogiſton being diſengaged in the ſtate of fire at liberty by the pure air which aſſumes its place: in the reduction of metals, the phlogiſton, in its turn, diſengages the pure air, and becomes fixed in theſe bodies. M. Lavoiſier, obſerving that the luminous appearance of the flame we have ſpoken of (and which too clearly evinces the preſence of light, or the matter of fire in action, to admit of controverſy), ſeemed rather to environ or ſurround the combuſtible, than to be diſengaged from it, adopted the opinion that the matter of light and heat is ſeparated from the pure or vital air, in proportion as the body burns and abſorbs a part of it. He now thinks that pure air, as well as every other aeriform fluid, is compounded of a peculiar principle, capable of becoming ſolid, and the matter of heat or fire, to which laſt it owes it aerial form; that it is decompoſed in combuſtion, its fixed and ſolid principle uniting with the combuſtible body, and by that means changing its nature, and adding to its weight, while the matter of fire is diſengaged in the form of light and heat †. So that what Stahl attributes to the combuſtible body, the modern doctrine aſcribes to the pure air; it being this laſt which burns, rather than the combuſtible, if combuſtion be made to conſiſt in the diſengagement of fire. As to the other principle, which, when united to the

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* Deſcribed in the Mem. de l' Acad. pour l' Ann. 1782. p. 461. *T.*

† The firſt ſketch of this theory was publiſhed in the Memoires de l' Acad. pour l' Ann. 1777, p. 592. It was afterwards explained at greater length in the volume for 1783, p. 505. *T.*

matter of fire, conſtitutes pure or vital air, though M. Lavoiſier has not yet entirely diſcovered its nature, yet as it is aſcertained that it almoſt always forms acids by combining with combuſtible bodies, he has called it the oxygenous, or acidifying principle *. It is this which produces the ſulphuric, arſenic, phoſphoric acids, &c. in the combuſtion of ſulphur, arſenic, phoſphorus, &c. it being one and the ſame ſubſtance in all theſe. It is to be obſerved, that in this new theory, the pure or vital air procured from metallic calces was not all contained in them; but is obtained from them, becauſe the oxygen united to the metals, combines with the matter of heat or light which paſſes through the veſſels, in which the calx of mercury is heated, &c.

Such is at preſent the ſtate of the ſcience of chemiſtry, with regard to the nature of atmoſpherical air, and its influence in combuſtion. The theory we have here exhibited daily acquires new force; the objections of thoſe who do not yet admit it, have done it no injury: they even prove, that, with a more accurate knowledge of the whole of this theory, the chemiſts who oppoſe it would be ſenſible of the inſufficiency of the objections they urge; and that, when this knowledge ſhall become more extended, all philoſophers will be neceſſarily of one ſentiment.

Reſpiration is a phenomenon very analogous to combuſtion. Like combuſtion it decompoſes the air: It can only be carried on in proportion to the quantity of pure or vital air which is preſent, and, when all that air is deſtroyed, animals periſh in the mephitic air which remains. It is a ſlow combuſtion, in which part of the heat of the vital air paſſes into the blood, which circulates through the lungs, and is with it diſperſed through all the organs: Thus it is that the animal heat is repaired, which is continually carried off by the atmoſphere and by ſurrounding bodies. The maintenance of the heat of the blood is therefore one of the principal uſes of reſpiration; and this happy theory explains why animals which do not reſpire the air, or which reſpire it very little, have cold blood.

Meſſieurs Lavoiſier and De la Place have diſcovered a ſecond uſe of air in reſpiration; namely, to abſorb a principle which exhales from the blood, and appears to be of the ſame nature as

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* Lavoiſier at firſt gave it the name of *oxigyne*, but the neceſſity of uſing an analogous term for ſome other ſubſtances improperly named, induced us to change the termination into *gene*, as being more expreſſive of its Greek derivation.

charcoal *. This body, reduced into vapours, combines with the oxygen of the vital air, and forms carbonic acid, which iſſues out of the lungs by the expiration. This formation of carbonic acid which takes place in atmoſpheric air reſpired by animals, at the ſame time that the mephitis is ſeparated, clearly ſhows the dangerous conſequences which reſult from too great a number of perſons being included in cloſe places, ſuch as theatres, hoſpitals, &c.; and the noxious effects, which air vitiated by reſpiration produces on perſons of delicate conſtitutions, are no longer to be wondered at.

We ſee, therefore, that two leading phenomena tend continually to vitiate and decompoſe the air which ſurrounds our globe. Theſe are combuſtion and reſpiration. This fluid would ſoon be rendered unfit for the maintenance of theſe natural proceſſes, if there were not other phenomena capable of reſtoring vital air to the atmoſphere, in the place of that which is continually abſorbed and loſt. We ſhall ſee, in the following chapter, and in the third part of theſe Elements, that vegetables poſſeſs very extended organs, deſtined by nature to extract this vital air from water, and to pour it forth into the atmoſphere, when the rays of the ſun act upon them.

§ 3. *Concerning the Characters of Mephitis, or Azotic Gas, which forms part of the Atmoſphere.*

From all the foregoing details, it follows, that atmoſpheric air is compoſed of two gaſes, or elaſtic fluids; the one, which maintains combuſtion and reſpiration; and the other, which cannot ſerve in the production of either of theſe phenomena. The firſt, which is called vital air, is in the proportion of 0, 27, or 0, 28; the other amounts to 0, 73, or 0, 72 [c]. We have obſerved that the former is compoſed of caloric, light and oxygen; the ſecond is likewiſe, as all gaſeous bodies are, a compound of caloric and of a baſe capable of becoming ſolid. This elaſtic fluid, which forms more than two thirds of the air of the atmoſphere, was at firſt called mephitis by Lavoiſier, becauſe it extinguiſhes bodies in combuſtion, and deſtroys animal life; but as all the gaſes, except vital and atmoſpherical air, are equally noxious, and as the name of mephitis is a general expreſſion which belongs to them all alike, and has always been given to elaſtic fluids, which are not reſpirable, we have adopted the name of azotic gas for this aeriform fluid; and this denomination has permitted us to give the name azote, or the ſubſtantive, to the baſe of this gas, which, like that of vital air, or oxygen, becomes fixed by combining with various ſubſtances. To give in this place ſome information reſpecting the nature of this azotic gas, we ſhall deſcribe ſome of its properties. It is ſomewhat lighter than atmoſpheric air, and occupies the upper part of rooms in which the air is altered by reſpiration and combuſtion. Though it is very noxious to animals in its ſtate of elaſtic fluidity, yet its baſe, or azote, is one of the component parts of their bodies, from which it is obtained in very great quantities. It is one of the conſtituent parts of volatile alkali, or ammoniac, and of the nitric acid. It appears to be abſorbed by vegetables, and perhaps even by animals. It is likewiſe very probable that it forms one of the principles of all the alkalis, and that it may be conſidered as the true alkaligen, oppoſed to the baſe of vital air, which, as we have obſerved, is oxygen. The atmoſphere would be then, according to theſe conſiderations, an immenſe reſervoir of the acidifying and alkalifying principles, without being itſelf either acid or alkaline.

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* Memoire ſur la Chaleur dans les Mem. de l'Acad. p. 1780. The firſt eſſay of Lavoiſier on Reſpiration, was read on the 3d May 1777. *T.*

All theſe properties can be no more than announceed in this place; they will be demonſtrated and explained much more fully in the other chapters. We have been deſirous of ſhewing the difference which exiſts merely between the two elaſtic fluids which conſtitute the air of the atmoſphere, and of fixing the attention on each of them[d].

NOTES ON CHAPTER VI.

[Page 197.]

[a] THE blue colour of the air, though rejected by Fourcroy, is admitted by many reſpectable philoſophers. It appears, from the very accurate obſervations of Sauſſure, that the blue colour of the ſky acquires a deeper ſhade in proportion as it is viewed from a more elevated ſituation. Conſult upon this ſubject Prieſtley's *Hiſtory of Viſion, Light, and Colours*, page 436, the *Journal de Phyſique*, March 1772, and *Sauſſure's Voyages dans les Alpes.*

[b] It is at preſent ſufficiently aſcertained, by the experiments of Dr. Beddoes, that theſe effects of air depend upon its oxygen, which probably combines either

with the matter diſcharged from the ulcerated or raw ſurface, or combines with the ſurface itſelf. It was long ago ſuggeſted by Berthollet, that the cauſticity of metallic oxyds depended on the affinity of their oxygen with animal matter; and the truth of this opinion was confirmed experimentally by Fourcroy. *Annales de Chimie*, tome 7ieme.

[c] This account of the compoſition of atmoſpheric air is not ſtrictly accurate, ſince the pureſt atmoſpheric air that has yet been found contains a mixture of carbonic acid gas. Cauſtic alkalis become mild, lime water acquires a pellicle on its ſurface, and metallic oxyds become effervescent in acids, after expoſure for a ſufficient length of time to atmoſpheric air. Theſe changes take place in every ſituation in which the experiments have been properly tried. Even upon the ſummit of Mont Blanc, there was a ſufficient quantity of carbonic acid gas in the atmoſpheric air to produce, in ſeven quarters of an hour, a pellicle upon the ſurface of lime water, and to communicate, in an hour and a half, the property of efferveſcing to cauſtic potaſh. It farther appears, that this ſmall quantity of carbonic acid gas adheres ſo ſtrongly to the atmoſpheric air, that the latter does not produce the ſlighteſt cloud when agitated with lime water. It was this, and other facts of the ſame kind, which induced Mr. Kirwan to conclude that the quantity of carbonic acid gas in atmoſpheric air is abſolutely inappreciable. Morveau has pointed out the circumſtances which occaſioned the failure of Mr. Kirwan's experiments, and has ſhown that atmoſpheric air contains a ſmall quantity of carbonic acid gas, even when it is unable to produce the ſmalleſt cloudineſs in lime water. Article *Air* of the chemical part of the *Encyclopédie Méthodique*, p. 745.

Atmoſpheric air alſo contains water; the quantity of which varies according to the temperature and denſity of the air, and according to the nature and qualities of the ſubſtances to which it has been recently expoſed. It appears, from the accurate experiments of Sauſſure, that a cubic foot of atmoſpheric air, having the temperature of 65°, diſſolves about 11 grains of water, in paſſing from extreme dryneſs to extreme humidity. Conſult upon this ſubject Sauſſure's *Eſſais ſur l'Hygrometrie*, § 97, 180.

[d] Neceſſary corrections in eſtimating the weight of any permanently elaſtic fluid from its volume.

1. The quantity of any gas is more conveniently aſcertained by meaſuring it than by weighing it, the weight being afterwards calculated from the volume and ſpecific gravity; but the common tables of ſpecific gravities being adapted for particular ſtates of preſſure and elaſticity in the elaſtic fluids to which they relate, it is neceſſary to make certain corrections in the obſerved volumes of theſe elaſtic fluids, when they are ſubjected to a difference of preſſure, or exiſt in a different ſtate of elaſticity.

2. The volume occupied by an elaſtic fluid is inverſely as the preſſure applied to it. This at leaſt is the caſe in thoſe variations of preſſure which occur in the atmoſphere, or in ordinary chemical experiments. From this obſervation we get the following general formula.

Let v = the preſent volume of any gas,
n = the preſent height of the mercury in the barometer,
n' = the height of the barometer, to which the tables of ſpecific gravity are adapted,
x = the volume which the gas would occupy, if the barometer ſtood at n';

Then $n : n' :: x : v$, and $x = \frac{nv}{n'}$

But there is another ſource of fallacy ariſing from the influence of preſſure upon the volume of elaſtic fluids. When gas is confined in a jar over mercury or water, it often happens that the mercury or water muſt be allowed to riſe within the jar, above the level of the mercury or water in the baſon. In that caſe the gas is not compreſſed by the whole weight of the atmoſphere, but only by the weight of the atmoſphere, *minus* the weight of the column of mercury or water in the jar above the level of the baſon. The preſſure to which the gas is ſubjected in theſe circumſtances may be calculated in the following manner:

Let H = the preſent height of the mercury in the barometer,
h = the height of the mercury or water in the jar above the level of the baſon,
v = the volume of gas in the jar,
x = the volume which it would have occupied, if it had been compreſſed by the whole weight of the atmoſphere;

Then $H : H-h :: v : x$, and $x = \dfrac{(H-h)\,v}{H}$

When mercury is uſed in the baſon, the application of this formula is made at once; but when water is uſed, we muſt firſt reduce the column of water to its correſponding column of mercury. This may be done very expeditiouſly, by means of the table (No. II.) annexed to Lavoiſier's Elements of Chemiſtry, or by recollecting that the ſpecific gravity of mercury is very nearly 13.6. The whole of this laſt calculation may be avoided, in ſome inſtances, by plunging the jar filled with gas into the baſon, till the liquid within the jar be on a level with the liquid without, and by calculating the quantity of the gas from the volume which it then occupies. But this method is not always practicable.

3. Air is expanded, like other ſubſtances, by caloric; but philoſophers are not perfectly agreed as to the ratio of its expanſion, the direct experiments which have been made to determine that point varying ſomewhat in their reſults.

Taking the medium of Sir George Shuckburgh's experiments, it appears that 1000 parts of atmoſpheric air, of the freezing temperature, increaſe in volume by 2.43 thouſandth parts, for every additional degree of temperature according to Fahrenheit's ſcale. Theſe experiments were made between the freezing point and this temperature of 51°. They indicate a leſs expanſion for the degrees near to the freezing point, and a greater expanſion for thoſe remote from it; but the expanſion of 2.43 thouſandth parts, or of 1-412th part for every degree, is the medium *.

The late General Roy's experiments agree pretty nearly with thoſe of Sir George Shuckburgh. He found, indeed, that 1000 parts of atmoſpheric air were expanded to 1484.21 parts, by paſſing from the freezing to the boiling temperature, which gives an expanſion of 2.284 thouſandth parts, or 1-438 nearly for every degree †; but from the 12th to the 92d degree, he makes the expanſion for every degree 1-409th part, which differs only by 2-10000th parts from Sir George Shuckburgh's eſtimate of the expanſion between 32° and 51°.

So far the direct experiments upon the dilatibility of air agree tolerably well; but thoſe of Sauſſure, which appear to have been made in very advantageous circumſtances, afford extremely different reſults. The quantity of air operated on by Sauſſure, was much greater than that contained in General Roy's apparatus, amounting to more than four cubic feet; the dilatations produced by the ſame increaſe of temperature, did not vary in his numerous experiments, by more than 1-11th of the whole; and yet the medium of his obſervations gave only 1.88615 thouſandth parts, a 1-530th part for the expanſion produced by every degree of temperature, from 44° to 81° *.

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* *Philoſophical Tranſactions for* 1777, page 563.

† *Ibid.* p. 703, 704.

Some late experiments, which appear to have been very carefully made by M. du Vernois, under the inſpection of Guiton Morveau, differ ſtill more widely than Sauſſure's from thoſe of the two Engliſh philoſophers. It appears from theſe experiments, that between 32° and 77°, the *mean* expanſion of atmoſpheric air is only 1-571ſt part for every degree of Fahrenheit's ſcale; that between 77° and 122°, it is 1-252.5th part; and between 122° and 167°, the 1-112th part †.

Lavoiſier, in his *Memoire ſur la Chaleur*, and in his *Elémens de Chimie*, has aſſumed a degree of expanſibility for atmoſpheric air, which is intermediate between theſe extremes. This degree was afforded him by the barometrical obſervations of De Luc; from which it appeared, that about the temperature of 70°, the atmoſpheric air is expanded by 1-215th part of its volume, for every degree of De Luc's thermometer; or by 1-480th part, for every degree of Fahrenheit's.

The hygrometric ſtate of the air is another circumſtance that influences its volume. Sauſſure found that the air, in paſſing from its drieſt ſtate to the ſtate of greateſt moiſture, expands by about 1-54th part of its volume; and returns again to its former volume, when reſtored to the ſtate of greateſt dryneſs ‡.

How far does the hygrometric ſtate of the air affect its dilatibility by caloric? It would appear from General Roy's experiments, that above the 40° or 45° of Fahrenheit's ſcale, the expanſibility of moiſt air is conſiderably and progreſſively greater than that of dry air ||; but Sauſſure aſſures us that between 44° and 81° the drieſt air is rather more expanſible than the moſt humid; and he ſuggeſts, with great appearance of truth, that General Roy had been miſled in theſe experiments, by not adverting to the formation of ſteam in his manometer, and its conſequent effect upon the inſtrument §.

It is proper to add, that ſlight variations in the denſity of air appear, from General Roy's experiments, to occaſion hardly any difference in its expanſibility; but great variations produce very marked effects in that property. Air ſubjected to the preſſure of 2½ atmoſpheres, is dilated by 1-488th part, at a medium, for every degree of temperature between the freezing and boiling points; and air preſſed with only 1-5th of an atmoſphere, expands by no more than 1-1271ſt part for every degree of the ſame ſcale. It would ſeem that atmoſpheric air of the common denſity is more expanſible by caloric, than when it is either very much condenſed, or very much rarefied ¶.

The dilatibility of atmoſpheric air has become an object of inquiry among natural philoſophers, becauſe the accurate determination of it is neceſſary for calculating heights, by means of the barometer; but the dilatations of the other elaſtic fluids, which are infinitely more intereſting to chemiſts, have not been favoured with the ſame attention. We have indeed little but conjecture upon this ſubject, except the ſeries of experiments which were made by M. du Vernois, under the direction of Guiton Morveau; and which are ſhortly deſcribed in the *Encyclopédie Méthodique*. The following table contains ſuch of the reſults of M. du Vernois's labours, as, in the opinion of Guiton, may be ſafely confided in. Though

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* *Eſſais ſur l'Hygrometrie, par H. B. Sauſſure*, § 113.

† *Encyclopédie Méthodique*, Chimie, *Air*, page 679.

‡ *Eſſais ſur l'Hygrometrie*, § 110.

|| *Philoſophical Tranſactions for* 1777, page 705 and 712.

§ *Eſſais ſur l'Hygrometrie*, § 113. Note.

¶ *Philoſophical Tranſactions for* 1777, page 700 and 701.

it may be obſerved, that ſome even of theſe have rather a ſuſpicious appearance; and it is much to be regretted, that in experiments otherwiſe ſo accurately made, no attention was paid, to free the gaſes from moiſture, or at leaſt to aſcertain their hygrometric ſtate.

TABLE of the Expanſions of Air, and of ſome of the principal Gaſes, obſerved for every 20° of Reaumur's Scale.

	From zero to 20°.	From 20° to 40°.	From 40° to 60°.	From 60° to 80°.
Atmoſpheric air expands,	$\frac{1}{12.67}$	$\frac{1}{5.61}$	$\frac{1}{2.49}$	
Oxygenous gas, -	$\frac{1}{22.12}$	$\frac{1}{4.92}$	$\frac{1}{1.53}$	
Azotic gas, -	$\frac{1}{29.41}$	$\frac{1}{5.41}$	$\frac{1}{1.82}$	$5+\frac{1}{57.2}$
Hydrogenous gas, -	$\frac{1}{11.91}$	$\frac{1}{6.92}$		
Nitrous gas, -	$\frac{1}{15.33}$	$\frac{1}{9}$	$\frac{1}{3.739}$	
Carbonic acid gas, -	$\frac{1}{9.049}$	$\frac{1}{5.099}$	$\frac{1}{2.31}$	
Ammoniacal gas, -	$\frac{1}{3.58}$	$\frac{1}{1.75}$	$1+\frac{1}{1.35}$	

It appears from theſe valuable experiments, that the dilatibility of the gaſes increaſes progreſſively, as they are raiſed to higher degrees of temperature; but the points of the thermometric ſcale at which M. du Vernois's obſervations were made, are too remote from one another, and not ſufficiently numerous, to indicate the rate of this increaſe. Till proper experiments be made for meaſuring accurately this progreſſive dilatibility, the following table may be of uſe. It is calculated from M. du Vernois's table, and contains the *mean* dilatations of the gaſes for every degree of Fahrenheit's ſcale, from 32° to the points where the preceding table terminates.

	From 32° to 77°.	From 77° to 122°.	From 122° to 167°.	From 167° to 212°.
Atmoſpheric air expands for every degree of temperature,	$\frac{1}{570}$	$\frac{1}{252}$	$\frac{1}{112}$	
Oxygenous gas, -	$\frac{1}{995}$	$\frac{1}{221}$	$\frac{1}{69}$	

	From 32° to 77°.	From 77° to 122°.	From 122° to 167°.	From 167° to 212°.
Azotic gas,	$\frac{1}{1323}$	$\frac{1}{243}$	$\frac{1}{82}$	$\frac{1}{88}$
Hydrogenous gas,	$\frac{1}{536}$	$\frac{1}{321}$		
Nitrous gas,	$\frac{1}{690}$	$\frac{1}{405}$	$\frac{1}{168}$	
Carbonic acid gas,	$\frac{1}{428}$	$\frac{1}{229}$	$\frac{1}{104}$	
Ammoniacal gas,	$\frac{1}{164}$	$\frac{1}{79}$	$\frac{1}{26}$	

CHAPTER VII.

OF WATER.

WATER had always been conſidered as an element performing a very extenſive part in almoſt all the phenomena of nature, capable of appearing under a great variety of forms, and of entering into many combinations, without ſuffering any alteration of its nature, or becoming unable to reſume its original condition. The late reſearches, however, of Meſſrs. Lavoiſier, Meuſnier, De la Place, and Monge, have ſhown, that water, as well as air, is formed of principles of greater ſimplicity, which may be obtained ſeparate from each other. This important diſcovery conſtitutes one of the moſt brilliant epochas in the hiſtory of chemiſtry. We ſhall afterwards ſee by what means theſe philoſophers were able to effect the analyſis of water; but we muſt firſt conſider the phyſical properties of this ſubſtance.

§ 1. *Concerning the Phyſical Properties of Water.*

Natural philoſophers define water to be an inſipid, ponderous, tranſparent, colourleſs, inelaſtic, and highly fluid body, ſuſceptible of the different ſtates of aggregation, from ſolidity to that of elaſtic vapour.

It is found in almoſt every natural body: There are, notwithſtanding, many ſubſtances with which art cannot unite it, though this is continually done in nature. It is obtained from wood, and the moſt ſolid bones: It exiſts in the hardeſt and moſt compact calcareous ſtones, and forms the greater part of the fluids, and a conſiderable proportion of the ſolid parts of animal and vegetable bodies. Theſe are the facts that have occaſioned it to be reckoned among the number of elements.

The naturaliſt conſiders water as exiſting in large maſſes, and filling the cavities or depreſſed places on the ſurface of the earth. Its natural hiſtory comprehends that of the ice, which is eternally exiſting on the tops of mountains, and in the polar regions; of the ſeas, lakes, rivers, and brooks; of the clouds, hail, ſnow, and rain. It is diſtinguiſhed into terreſtrial and atmoſpheric waters; and its motion or tranſitions become a ſubject of meteorological inquiry. It ſucceſſively paſſes from the ſurface of the globe into the atmoſphere, and from the atmoſphere to the mountains, where it is condenſed into ſtreams that are the origin of ſprings and rivers, by which it directs its courſe to the grand reſervoir, the ſea. When we attend to the phenomena of this immenſe body of water, and obſerve its agitation by winds, its libratory motion or alternate riſe and fall on the coaſts, called the tides, and its currents; when we perceive the effects of theſe and other motions, by which mountains are gradually formed, harbours in ſome places deſtroyed, inundations produced in others, and other coaſts again left dry; when we behold iſlands riſing from the bottom of the ſea, and others ſubmerged; we cannot but acknowledge that water is one of the moſt powerful agents in nature. If we tranſport ourſelves in imagination into the vaſt receſſes of the interior parts of the earth, we ſhall again meet this element acting in ſilence in the formation of ſalts and cryſtals, and depoſiting them in the clefts of the rocks. Theſe great ſubjects form a part of the natural hiſtory of water; but they cannot be properly explained, till the phyſical and chemical properties of this ſubſtance have been treated of.

The moſt ſtriking property of water is, its quality of aſſuming the ſeveral ſtates of ſolidity, fluidity, or vapour. Let us conſider each of theſe modifications.

Concerning Water in the State of Ice.

Ice ſeems to be water in its natural ſtate; for the natural ſtate of a body, chemically conſidered, is that in which it has the ſtrongeſt poſſible aggregation. But as water is moſt abundantly found in the liquid ſtate, this laſt has been conſtantly regarded as the natural ſtate of water.

The formation of ice is attended with ſeveral concomitant circumſtances, which well deſerve to be conſidered.

1. A heat of ſome degrees of Reaumur's thermometer is produced in the water by the act of freezing, as is always the caſe when a liquid body is changed into a ſolid. This thermometer, plunged into the water beginning to freeze, will indicate a temperature ſome degrees above zero; though another thermometer, placed in the ſurrounding atmoſphere, ſufficiently cold to freeze water, will remain at this point, or even ſink below it. It follows, therefore, that a portion of the heat which was fixed in the liquid water is diſengaged when it becomes converted into a ſo-

lid; and accordingly we find the ſpecific heat of ice inferior to that of water[a]. The ſame heat is obſervable in the cryſtallization of ſalts *.

2. The acceſs of air favours the production of ice. Water in a well-cloſed veſſel freezes very ſlowly; but if the veſſel be opened, it freezes much more quickly, and ſometimes in the inſtant of expoſure to the contact of the air. This phenomenon is ſimilar to that which happens in the cryſtallization of ſalts. Solutions of ſalts in cloſed veſſels frequently exhibit a ſudden cryſtallization when uncovered, and expoſed to the contact of air.

3. A ſlight degree of agitation likewiſe accelerates this formation; in which reſpect, alſo, we find a ſimilitude between this and the cryſtallization of ſalts †. By agitating certain ſaline ſolutions which do not uſually afford cryſtals, it is ſometimes found that they are by that means produced. We have often ſeen this in ſolutions of calcareous nitrates and muriates. Theſe analogies between the formation of ice and of ſaline cryſtals prove that the former is obtained by a true cryſtallization.

4. Ice ſeems to have a greater bulk than the water had before it was frozen[b], and even breaks, by its expanſion, the veſſels in which it is formed[c]. It is not, however, the water itſelf which has acquired a greater volume in this caſe; but the air which is ſeparated from the water during congelation is the true cauſe of the increaſe of bulk ‡[d].

The following are the Properties of Ice.

1. When ſlowly formed, its cryſtals have the figure of needles, croſſing each other at an angle of 60 or of 120 degrees, according to the obſervation of M. Mairan. Sometimes its cryſtallization takes a determinate and regular form. M. Pelletier, the

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* The extrication of caloric is manifeſted by the increaſe of temperature, which takes place upon the congelation of water which has been cooled below the freezing point; but it is not true that the temperature ever riſes beyond that point. In fact, the congelation ſtops the moment the unfrozen part of the water has arrived at the higheſt temperature which ice is capable of ſuſtaining without melting; and in the natural proceſs, the congelation is continued by the low temperature of the air, and other ſurrounding bodies, which conduct off the heat. T.

† See a paper, by Dr. Black, on this ſubject, in *Philoſophical Tranſactions for* 1765. T.

‡ The difficult queſtion concerning the expanſion of water by freezing, is not yet well reſolved. If it depended on the excluded air, it might perhaps be poſſible, by proper management, to obtain ice more denſe than water. T.

ſcholar of D'Arcet, and member of the College of Pharmacy, obſerved, in a piece of fiſtulous ice, cryſtals in the form of flat quadrangular priſms, terminated at the ends by dihedral pyramids, though with great varieties. If, on the contrary, water, in a conſiderable maſs, be frozen ſuddenly, it forms only an irregular ſolid, in the ſame manner as happens when ſaline liquids are too much evaporated, and cooled ſuddenly.

2. Its conſiſtence is ſuch, that it may be reduced to duſt ſo ſmall as to be driven by the wind. In very cold climates the ice is ſo hard, that it is cut like ſtones, and has been employed in the conſtruction of edifices. We are aſſured, that even cannons have been bored out of ice, which have been charged with powder, and diſcharged ſeveral times before they melted.

3. Its elaſticity is very ſtrong, and much more remarkable than that of fluid water. Every one knows that a ball of ice, thrown on a hard ſurface, rebounds in the ſame manner as other ſolids.

4. It has a lively taſte, approaching to cauſticity. The impreſſion of ice on the ſenſe of feeling is univerſally known. Phyſicians employ it as a tonic or diſcutient, &c.

5. Its ſpecific gravity being leſs than that of water, it ſwims on the ſurface[e]. This phenomenon, as we have already obſerved, ariſes from a great quantity of air interpoſed between its parts. The property of expanſion, by freezing, is common to many other bodies, ſuch as butter, tallow, wax, &c.[f]; and is always owing to the air interpoſed between their particles; for every ſubſtance, ſingly conſidered, is more denſe and heavy in its ſtate of ſolidity than when fluid.

6. Its tranſparency is leſs than that of water, in conſequence of the bubbles of air which it contains, at leaſt in ſuch maſſes as are not regularly cryſtallized. This may be eaſily ſeen by an attentive examination of a piece of ice; and if the cavities be opened under water, the air is diſtinctly ſeen to iſſue out in bubbles.

7. It melts at ſome degrees of temperature above 0° in Reaumur's ſcale (or 32° of Fahrenheit), the liquefaction proceeding gradually from the ſurface to the internal parts[g].

8. In its paſſage from the ſolid to the fluid ſtate, it produces cold in the ſurrounding atmoſphere. Modern chemiſts think that it abſorbs heat in melting; and that this abſorption is equal with regard to the quantity of caloric which becomes fixed, and the

quantity of heat which is diſengaged when it becomes congealed. All bodies capable of freezing and melting, exhibit the ſame appearance, according to the different temperatures to which they are expoſed.

Concerning Water in the Fluid State.

The properties of fluid water are very different from thoſe of ice.

1. It has much leſs taſte than ice, and is commonly ſaid to be inſipid; yet thoſe who habitually drink water find differences, which ſhow that it has a conſiderable degree of taſte.

2. Its elaſticity is leſs; and has been denied, in conſequence of the experiments of the Academy del Cimento. But the Abbé Mongez has proved*, by an intereſting ſeries of experiments, that it is ſlightly elaſtic; and even ſhows, that the experiments of thoſe academicians confirm the ſame, becauſe the metallic ſpheres continued to exude drops of water after they had been taken from under the preſs; which could not have happened, if the water had not been diminiſhed, as to its dimenſions, by the compreſſion.

3. Its ſtate of liquid aggregation gives energy to its force of combination. Hence it has been called the grand diſſolvent of nature. In fact, it unites with a great number of bodies, and ſingularly favours their mutual combination.

4. It does not ſeem to unite with light, which merely paſſes through it. It is known that this laſt alters its courſe in entering into water, ſo as to paſs in a more perpendicular direction than before.

5. Heat dilates it, and converts it into the gaſeous ſtate [b]. Its ebullition conſiſts in this paſſage from the ſtate of liquidity to that of an aeriform fluid. This phenomenon ariſes from one part of the water having taken the form of an elaſtic fluid, and becoming inſoluble in the remaining liquid. Each bubble riſes from the bottom, and breaks at the ſurface, where it is diffuſed and diſſolved in the air. We have explained the cauſe of ebullition at large in our *Memoires de Chimie*, publiſhed in 1784, page 334.

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* The compreſſibility of water was proved long ſince by John Canton, F. R. S. by experiments made under the receiver of the air-pump; for which, ſee the *Philoſophical Tranſactions*. T.

The weight of the atmoſphere has a ſingular influence on the ebullition of water. In proportion as this weight is greater, ſo much the more does it oppoſe the tendency in the water to aſſume the form of vapour. This accounts for the obſervation of Fahrenheit, that the temperature of water in a ſtate of ebullition is not always the ſame. If the elevation of the mercury in the barometrical tube be attended to, it will be found that the temperature of boiling water is higher or lower according to that elevation.

This influence of the gravity of the air on ebullition muſt take place, eſpecially at different heights in the atmoſphere. So that water will, in like circumſtances, boil more eaſily, and with a leſs degree of heat on the mountains than in valleys, or on plains leſs elevated. All fluids aſſume the vaporous ſtate very readily at great heights: And, for this reaſon, volatile liquids, as ſpirit of wine, ether, alkaline or ammoniac gas, loſe the greateſt part of their ſtrength on high mountains; as has been obſerved by philoſophers, and lately by M. de Lamanon, at the height of more than 1800 toiſes above the level of the ſea. When the weight of the atmoſphere is taken off a veſſel of water placed in the receiver of an air-pump, we obſerve it to boil with great violence, and become converted into vapour, though at a temperature not exceeding 120 degrees of Fahrenheit[i].

A third circumſtance which influences the ebullition of water, excluſive of heat and the weight of the atmoſphere, is the humidity or dryneſs of the atmoſphere. But this property, being entirely chemical, will be attended to in the next paragraph.

6. If water be heated in cloſed veſſels, with an apparatus proper to receive the vapours, theſe laſt, when condenſed by cold, form diſtilled water. By this means, it is obtained pure, and ſeparate from the ſaline and earthy matters by which natural waters are almoſt always contaminated, and which do not riſe with the vapour. Chemiſts, who require very pure water for their experiments, procure it by diſtillation. They put river or ſpring water into a cucurbit of copper, lined with tin, to which a head of the ſame metal, with a refrigeratory, containing very cold water, is adapted; and the diſtilled water is received in very clean glaſs veſſels. It is proper to be obſerved, that, in order to have very pure diſtilled water, the veſſels ſhould be uſed for no other purpoſe. The veſſels intended to diſtil quickly, ſhould be made

on the new principles; that is to ſay, the cucurbit and its head ſhould be of a flattened figure, their horizontal being much longer than their vertical diameter. Water obtained by careful diſtillation, thus conducted, is perfectly pure. Chemiſts formerly made uſe of ſnow or rain water; but it is at preſent well known, that theſe waters often contain foreign bodies in ſolution.

Diſtilled water has a flat or faint taſte, and cauſes a ſenſation of weight at the ſtomach; but by being ſtrongly agitated in contact with air, it acquires a lively taſte, and may be drank without inconvenience. Diſtillation makes no change in pure water, except that of depriving it of the air it naturally contains, which gives it that freſh and lively taſte required to make it potable[k]. Boerhaave diſtilled the ſame water five hundred times, without obſerving any change produced in it. Some philoſophers have affirmed, at different periods, that water becomes changed into earth; becauſe, at each diſtillation, it leaves a certain quantity of earthy matter at the bottom of the veſſel. M. Lavoiſier has made experiments reſpecting this fact. Having weighed the veſſels he uſed in diſtilling water, as well as the quantity of water, and the reſidue it affords, he has ſhown that this earth is nothing but the matter of the veſſels gradually corroded by the water *.

Concerning Water in the State of Vapour, or Elaſtic Fluid.

When water is reduced to the ſtate of vapour by the action of fire, it acquires peculiar properties, which it had not in its two former ſtates of aggregation[l].

1. It is perfectly inviſible when received in the atmoſphere, provided the thermometer ſtands higher than 65 degrees, and the air be not already too highly charged with humidity.

2. If, on the contrary, the atmoſphere have a temperature below 55 degrees, and be charged with humidity, the vapour of water forms a whitiſh cloud, ſenſibly opake; which ariſes from the vapour not being abſorbed, or diſſolved by the humid air, as we ſhall afterwards explain, and conſequently to a true precipitation.

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* In addition to theſe obſervations on fluid water, it may be obſerved, that its temperature ceaſes to increaſe when the evaporation has arrived at a certain degree of rapidity; that this ſtationary point is higher in proportion to the difficulty the vapours find in making their eſcape; that if the vapour be prevented altogether from eſcaping, as is done in the digeſter of Papin, it will acquire, by the application of heat, a temperature approaching to ignition, and will diſſolve or act on earths and other bodies, which in other caſes it does not ſenſibly affect. T.

3. Its dilatation is ſuch, that by the moſt accurate computation, it is found to occupy eight hundred times the ſpace it poſſeſſed in the fluid form [m], according to Mr. Watt.

4. Its elaſticity is ſuch, as to produce the moſt terrible exploſions when confined. This power is uſefully employed in mechanics, of which application the engine for raiſing water, commonly called the ſteam engine, is an admirable inſtance, well known both to philoſophers and artiſts [n].

5. According to one of the moſt conſtant laws of the affinity of compoſition, it has a ſtronger tendency to combination in this ſtate, wherein its aggregation is the moſt feeble, than in either of the two others. Chemiſts have frequent occaſion to obſerve with what rapidity water, in the ſtate of vapour, diſſolves ſalts, ſoftens extractive and mucilaginous matters, corrodes and calcines metals, &c.

6. It is perfectly diſſolved in air. When it is ſlowly depoſited out of the atmoſphere, it conſtitutes dew. This diſſolution is performed in the ſame manner as thoſe of ſalts in water, as M. Le Roi, phyſician at Montpellier, has ſhown in an excellent diſſertation on the elevation and ſuſpenſion of water in air. *Mélanges de Phyſique et de Médicine*, Paris, 1771, 8vo.

7. One of the moſt ſingular phenomena reſpecting water in a ſtate of vapour, is the property it poſſeſſes of accelerating the combuſtion of oil when on fire; as is ſeen in the experiment of the eolipile applied to the enamellers lamp, or to common fires of pit-coal or wood, or fats in a ſtate of inflammation, which cannot be extinguiſhed by water, and even the burning of which it increaſes. Theſe phenomena induced Boerhaave to conclude that flame is, for the moſt part, compoſed of water. We ſhall preſently ſee that this happy conjecture of Boerhaave, nearly approaches to the modern diſcoveries on water; as we ſhall ſhow that this fluid increaſes the flame, in conſequence of its being itſelf decompoſed by the combuſtible bodies.

8. Laſtly, Water in the form of vapour, and diſſolved in the air, is condenſed and precipitated in part when expoſed to a degree of cold ſome degrees above the freezing point, it then reſumes its liquidity, as is ſeen in the falling dew. Sometimes, when the cold is beneath the freezing point, it is converted into ſmall cryſtals of ice. Such is the origin of thoſe ramified incruſtations of ice formed on the internal ſurface of the glaſs in

windows during intenſe froſts; and the ſame cauſe in Siberia, and other very cold climates, converts the moiſture of the breath into a kind of ſnow.

§ 2. *Concerning the Chemical Properties of Water.*

There is no body ſuſceptible of a greater number of combinations than water; hence it has long been called the grand ſolvent of nature. It is on this account that the waters of the ſea, of lakes, rivers, ſprings, and fountains are very far from being pure, and always contain various foreign matters, eſpecially ſaline ſubſtances.

Water may combine with air in two different manners: 1. It may abſorb this elaſtic fluid, and become charged with it while in its liquid ſtate. It is to its combination with air that it owes its freſh and agreeable taſte. The exiſtence of air in water has long ſince been diſcovered by means of the air pump; for in proportion as the air above the water is exhauſted, the eſcape of bubbles ſhows that it likewiſe contained air. By diſtillation of water in the pneumato-chemical apparatus, air is obtained. When water is boiled, the firſt bubbles are cauſed by the eſcape of air, and the lively taſte no longer remains; but this laſt is reſtored by expoſure to the air, or more quickly by agitation therein. 2. The air diſſolves water, and renders it elaſtic and inviſible when it poſſeſſes a certain degree of heat; the hotter it is, the more water it will hold in ſolution. M. le Roi, phyſician at Montpellier, has examined very minutely into the ſtate of the water in the atmoſphere. The ingenious experiments he has made, ſhow that heated air, apparently dry, when encloſed in a glaſs veſſel, depoſits, on cooling, the water it was overcharged with, which appears in drops; that this quantity is different according to the temperature of the air; that it is precipitated during the night, and conſtitutes a particular kind of dew. He even thinks, there is reaſon to conclude from theſe facts, that the variations of the weight of the atmoſphere depend in part upon this water, which abounds more or leſs, as the temperature varies[o].

Though the order we have adopted ſeems to require that we ſhould not yet enter into the conſideration of ſaline matters, we muſt, nevertheleſs, obſerve in this place, that water diſſolves theſe matters very readily, and always contains a certain proportion of them. Calcareous ſalts, in particular, are ſubſtances which communicate diſagreeable and often noxious qualities to the waters of wells, brooks, and rivers. The carbonic acid, clay, iron, and the extracts of vegetables altered by putrefaction, are likewiſe found in waters. Waters thus vitiated, are very unfit to be uſed as drink; ſuch as abound with calcareous earth are called crude or hard water; their taſte is flat, and they produce a ſenſe of weight on the ſtomach; they retard digeſtion; ſometimes they have the effect of purgatives, and the uſe of them may even be productive of dangerous conſequences. It is therefore very neceſſary to poſſeſs the means of knowing them, of determining with what ſubſtances they are vitiated, and of extracting thoſe ſubſtances where it can conveniently be performed.

Water proper to be drank is diſtinguiſhed by the following characters: It is very clear and limpid, its tranſparency being altered by no foreign ſubſtance; it has no kind of ſmell; its taſte is lively, freſh, and in a manner penetrating; it boils readily, and without loſing its tranſparency by the ſeparation of any ſubſtance; it diſſolves ſoap, ſo as to form an homogeneous fluid without clouds or lumps; it boils leguminous vegetables without communicating hardneſs to them. On the addition of the liquids called re-agents, ſuch as alkalis, or the nitrous ſolutions of mercury or ſilver, it does not ſenſibly loſe its tranſparency. And, laſtly, it paſſes readily through the ſtomach and inteſtines, and promotes digeſtion. All theſe good qualities are found in the water of a ſpring or a river which paſſes through a ſandy ſoil, is agitated by a conſtant motion, and is not charged with putrefying vegetable or animal matter. It is a neceſſary condition, therefore, that no common ſewers or drains ſhould paſs into it; that its current ſhould not be impeded or rendered ſlower by obſtacles, or by the water being drained off in too great quantities; that the watering of hemp, or the waſhing of clothes in ſoapy lixiviums ſhould not be performed in it, &c. &c. On the contrary, ſuch waters as ſtand without motion in ſubterraneous cavities, which come from a calcareous or gypſeous ſoil, have no real current, abound with plants and inſects, have little depth, and reſt on a muddy bottom, compoſed of putrefied vegetables, poſſeſs properties altogether the reverſe of thoſe we have pointed out as good. Their taſte is either flat or nauſeous; their ſmell mouldy or lightly putrid; their colour often green or yellowiſh, with mucilaginous or fibrous green or brown remains of vegetables in a ſtate of putrefaction floating therein; they give a green colour to vegetable blues; become turbid by boiling; form clouds with ſoap; harden pulſe by boiling; afford precipitates more or leſs abundantly by means of the re-agents; and, laſtly, they produce a ſenſe of weight at the ſtomach, paſs with difficulty through the inteſtines, and impede the action of the digeſtive powers.

To correct theſe bad qualities, ſeveral methods are employed, entirely grounded on chemical or phyſical conſiderations.

1. Stagnant waters are ſet in motion by digging a canal with a proper declivity, where the ground will admit of it; agitating them by means of mills, or cauſing them to paſs through the air in the form of jets, caſcades, &c. Theſe methods facilitate the evaporation of the noxious gas and putrid ſpiritus rector the water may contain, cauſe impurities to ſubſide by uniting them into larger maſſes, and occaſion the abſorption of a proper quantity of atmoſpheric air, &c.

2. Marſhes and ſtanding waters are to be cured by carrying away the vegetable and animal matters which are ſuſceptible of putrefaction, and which prevent the due courſe and conſequent agitation of the water.

3. Water is filtered in jars or other apparatus, whoſe bottoms are covered with fine ſand and ſponges; theſe are to be renewed from time to time. The beds of ſmall rivulets are cleared of the mud, and a proper quantity of ſand placed inſtead thereof.

4. Theſe methods purify water, by ſeparating the heterogeneous matters that float therein, but do not deprive it of the ſaline ſubſtances it may contain. To ſeparate theſe, it muſt be boiled and decanted after ſubſidence, or filtrated through paper, or clear white ſand, and expoſed to the air in ſhallow earthen or ſtone veſſels. It may then be uſed for common drink without danger; for ebullition takes away the diſagreeable flavour, and cauſes a part of the calcareous ſalts to precipitate from hard waters. Water for theſe purpoſes ſhould be kept boiling for half an hour, or till it has acquired the property of diſſolving ſoap, or boiling pulſe, without rendering them hard.

5. If ebullition be found inſufficient to deprive waters of the calcareous ſalts, as commonly happens when theſe matters are in great abundance, a ſmall quantity of potaſh muſt be added in the

boiling; or, if that be not at hand, wood aſhes may be uſed. Theſe occaſion a precipitation; and the water, after decantation and expoſure to the air, is perfectly wholeſome.

6. Subſtances proper to counteract or prevent the bad effects or noxious qualities of water may be added, ſuch as ſugar, honey, meal, barley, wheat, pot-herbs, or labiated and aromatic vegetables. But theſe additions do not communicate the lightneſs and other good qualities of pure water, and, in fact, only ſubſtitute one taſte for another [p].

This account of the chemical properties of water does not extend to the conſideration of its power as an agent in combinations, into a great number of which it enters; but in many of theſe it ſuffers a ſingular alteration, which has not been till within theſe few months diſcovered (April 1784), and which deſerves all the attention of chemiſts. It has been long known that water, in certain caſes, favours combuſtion, as in the enamellers lamp, the inflammation of oil, at great fires, &c.; and ſome philoſophers have thought it might be concluded from theſe facts that water is converted into air. It is to ſeveral French academicians that we are indebted for a more accurate knowledge of theſe phenomena of the nature of water. Lavoiſier having remarked with Mr. De la Place, that when inflammable gas is burned with vital air in cloſed veſſels, pure water is produced (a fact which Mr. Monge obſerved, with the greateſt preciſion, in the laboratory of The School de Meziere, nearly at the ſame time with himſelf), thought it juſt to conclude, that water was formed in this experiment by the combination of pure and of inflammable gas, which he regarded as its conſtituent principles. This theory of the nature of water, by which M. Lavoiſier deprived it at once of its prerogative as a ſimple body and as an element, met with ſuch oppoſition, as convinced him that the decompoſition of water was a proof neceſſary to be added to the ſynthetical examination of that ſubſtance. He therefore endeavoured to decompoſe this fluid, by preſenting to it ſuch bodies as might be expected to ſeparate one of its principles. He aſſociated himſelf with M. Meuſnier for the purpoſe of making theſe inquiries; and theſe two philoſophers read a Memoir at the Royal Academy of Sciences, the 21ſt of April 1784, wherein it is proved that water is not a ſimple ſubſtance, but is compoſed of the baſe of inflammable gas and pure air, or oxygen, which may be eaſily ſeparated from each other. To obtain them ſeparate, Mr. Lavoiſier firſt made uſe of the following proceſs: He placed in a ſmall glaſs veſſel, inverted over mercury, a known quantity of very pure diſtilled water and iron filings. The metal was gradually and ſlowly calcined, and an elaſtic inflammable fluid was collected above the mercury; the quantity of water becoming leſs in proportion as the two phenomena were produced. After a length of time, the iron may be had entirely calcined, and the water totally decompoſed; for it is this fluid, which, according to Mr. Lavoiſier, affords the inflammable gas, and calcines the iron. As it is compoſed of oxygen and the baſe of inflammable gas, the iron by degrees attracts and combines with the former, with which it forms a metallic oxyd, at the ſame time that it diſengages the inflammable gas. Such was the firſt experiment by which this learned chemiſt decompoſed water; but in his experiments with Mr. Meuſnier, he employed a much more ſhort and concluſive proceſs. He cauſed water to paſs, drop by drop, through a gun-barrel, placed in a furnace, and kept at a red heat: The water in the ſtate of vapour is decompoſed by the contact of the iron; the oxygen it contains becomes fixed in the iron, as is proved by the augmentation of its weight, and the ſingular alteration it undergoes; and the baſe of the inflammable gas, ſet at liberty, paſſes ſwiftly through the gun-barrel, and is received in inverted glaſſes, properly adapted at the other end. By repeating theſe experiments with all poſſible accuracy, theſe philoſophers found, that water contains ſix parts of oxygen united to one of the baſe of inflammable gas, and conſequently that this laſt conſtitutes only a ſeventh part of the compound; that it is nearly thirteen times as light as atmoſpheric air, and may occupy a ſpace fifteen hundred times greater than it poſſeſſes in its aqueous combination.

Water appears to be capable of acting in the ſame manner on many other combuſtible bodies, and reduces them, with different degrees of facility, to the ſtate of burned bodies, affording at the ſame time inflammable gas. In this manner, it has been decompoſed by zinc, charcoal, and oils. The experiment with this laſt mentioned ſubſtance, is made by letting water fall, drop by drop, into boiling oil, in a retort, whoſe neck is plunged in water beneath the uſual pneumatic chemical apparatus; but it requires great precaution to avoid the exploſions which take place from the water riſing[*] in the neck of the retort, in conſequence of the vacuum formed within during the ebullition. In order to know whether a combuſtible body, as a metal or charcoal, &c. is capable of decompoſing water, nothing more is neceſſary, than to plunge it red hot into a veſſel of water, over which is inverted a glaſs veſſel, likewiſe filled with the ſame fluid. The inflammable gas, which is always diſengaged when water is decompoſed, will be collected under the glaſs veſſel. This is the cauſe of the bubbles produced by plunging red-hot iron into water, and the inflammable air collected in that caſe, as has been obſerved by Meſſrs. Haſſenfratz, Stouttz, and d'Hellancourt, of the Royal Mineralogical School of France. The ſame diſengagement of inflammable gas, produced by the decompoſition of water, takes place when ignited charcoal is plunged therein.

Theſe are the facts lately diſcovered concerning the nature and compoſition of water. Meſſrs. Lavoiſier and Meuſnier therefore think that this fluid is compoſed of ſix parts of oxygen, and one of the baſe of inflammable gas; or, more accurately, 0,86 of the former, and 0,14 of the latter of theſe ſubſtances: That iron, charcoal, and oils, having a greater affinity with oxygen than the laſt has with the baſe of inflammable gas, ſeize it, and decompoſe the water entirely; the inflammable air eſcaping in an elaſtic form: That water is recompoſed by burning theſe two kinds of air together, which, if carefully performed, affords a quantity equal in weight to that of the two fluids made uſe of: That water is thus produced in a great number of chemical operations; as for example, when ſpirit of wine or oils are burned under a chimney, adapted to the worm-pipe of a ſtill, whoſe other extremity is adapted to a recipient, a quantity of water is collected, which is almoſt always greater than that of the inflammable fluid made uſe of; which is occaſioned by the inflammable gas of theſe liquids combining with the vital air of the atmoſphere, by which their combuſtion is maintained.

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[*] This very common and diſagreeable accident, attendant on chemical operations, is prevented by Mr. Babington, of Guy's Hoſpital, by a ſimple and ingenious contrivance. The part of the apparatus plunged in the water is made of a conſiderable diameter, and is immerſed to ſuch a depth, that the ſubſidence of the external ſurface of the water is ſufficient to ſuffer air to enter, before the internal water has riſen ſo as to reach the body of the veſſel. In caſes where the admiſſion of atmoſpheric air would do harm, he injects phlogiſticated air, when the aſcent of the water ſhows it to be neceſſary. T.

M. M. Van Trotzwick and Deiman have diſcovered that water is decompoſed by the paſſage of the electric ſpark; and that it is ſeparated into two elaſtic fluids, which inflame and recompoſe water, when this ſpark is excited in them. This beautiful experiment affords a ſufficient anſwer to the greater part of the objections which have been made to the decompoſition of this ſubſtance. See *Journ. de Phyſ.* for 1783, and the *Ann. de Chem.* tom. 4.

Theſe diſcoveries, and the theory theſe philoſophers have deduced from them, will, no doubt, conſtitute one of the moſt brilliant periods of philoſophical ſcience. But as it is of the utmoſt conſequence to examine the reſults and conſequences with all poſſible care, we think it proper to make ſome obſervations in this place, in order to render this theory more clear and accurate.

We have obſerved, that all aeriform fluids owe their gaſeous ſtate to the matter of fire or heat which is united to them. It is the ſame with inflammable gas. Now, as the decompoſition of water, and its converſion into inflammable gas, never take place but at a temperature conſiderably elevated; and as its rapidity is greater in proportion as the heat is ſtronger; we ſee that this gas does not poſſeſs the aeriform ſtate, nor acquire ſo much levity, but becauſe its baſe, which partook of the liquidity of the water, abſorbs a great quantity of heat; ſo that it cannot be obtained but in this ſtate of extreme fuſion. It is neceſſary, therefore, to give a name to this baſe of inflammable gas, which, when it is combined to that of vital air, or oxygen, in water, may even become ſolid, as is conceived in ice. This baſe, conſidered as one of the eſſential principles of water, ought to have a name expreſſive of this property. We have adopted the word hydrogen, which very well anſwers the propoſed intention: We ſay, therefore, that water is a compound of the baſe of vital air, or oxygen, and the baſe of inflammable gas, or hydrogen; and as many bodies are inflammable in the ſtate of elaſtic fluids, ſuch as alcohol, ether, the volatile oils, &c. we diſtinguiſh this principle of water, in the aeriform ſtate, by the words hydrogenous gas.

We ſhall return to this important ſubject in another chapter. It is ſufficient to have ſhown in the preſent, that water is not a ſimple ſubſtance, but is ſuſceptible of decompoſition. Nature, in the large way, effects the diſunion of its principles with much more facility, and by a greater number of proceſſes than art poſſeſſes. It is by its decompoſition that water ſerves to purify the atmoſphere, by emitting vital air; that large quantities of inflammable gas are diſengaged from ſtagnant water; that the atmoſphere is ſometimes ſo highly charged with it, that the re-eſtabliſhment of the equilibrium of the electric fluid ſets it on fire, and gives riſe to fiery meteors; that water contributes to the formation of ſaline matters, acids, of which oxygen is conſtantly one of the principles. Laſtly, This brilliant diſcovery of the principles of water, its decompoſition and recompoſition, throws great light on many phenomena of nature; and, in particular, on the renewal of the atmoſphere, the ſolution of metals, vegetation, fermentation, putrefaction; as we ſhall fully explain in the ſeveral chapters of this work[q].

NOTES ON CHAPTER VII.

[Page 216.]

[a] THE quantity of caloric diſengaged during the converſion of a pound of water into ice, is, according to Dr. Black, the original diſcoverer of this important fact, equal to 140° of Fahrenheit. Lavoiſier eſtimates it at 5° leſs. See *Crawford on Animal Heat*, p. 72, 73. *Lavoiſier's Elements of Chemiſtry*, Edin. edit. p. 432, 433.

[b] When water is cooled down to 40° of Fahrenheit, it ceaſes to contract by the farther diminution of its temperature, but, on the contrary, begins to expand till it arrives at the freezing point, when an inſtantaneous and more conſiderable expanſion occurs. This fact was firſt noticed by De Luc, and afterwards confirmed by Sir C. Blagden. See *Phil. Tranſ.* Vol. LXXVIII.

[c] The force with which the water expands, while converting into ice, is ſo great, as to be almoſt incredible. Several philoſophers have endeavoured to meaſure the degree of this force; and from their computations it would appear that the expanſion of a cubic inch of water, during its converſion into ice, is ſufficient to raiſe a weight of 2700 lb. The knowledge of this fact affords a ready explanation of the manner in which trees are often ſplit, and even the hardeſt rocks rent aſunder, during intenſe froſt.

[d] This explanation is by no means adequate to account for the phenomenon. The force with which the ice expands is greater than what can poſſibly ariſe from the ſucceſſive diſengagements of ſmall portions of ſo compreſſible a fluid as air; and beſides, it is known that the volume of a given quantity of water, deprived completely of its air by boiling, or by means of the air pump, is very ſenſibly increaſed during its converſion into ice. We are, therefore, inclined to aſcribe, with M. Mairan (in his *Deſertation ſur la Glace*), this increaſe of bulk to the new, regular, and cryſtallized arrangement which the particles of water aſſume in freezing.

[e] The ſpecific gravity of ice is ſaid to be about 1-10th leſs than that of water; but it muſt obviouſly vary in proportion to the quantity of air which the water

contains, the degree of cold to which it is expoſed, the ſuddenneſs of the congelation, &c. Hence ice formed from water previouſly deprived of its air is found to be harder, more tranſparent, and heavier than common ice.

[f] This expreſſion is perhaps too general; for not only water, but ſome of the metals (iron for example), appear to expand a little in paſſing from the liquid to the ſolid ſtate. We have a proof of this in the very ſtrong impreſſions metals receive from the moulds in which they are caſt.

[g] Ice evaporates alſo at a temperature below that at which it melts into water. This is proved not only by the diſappearance of hoar froſt from poliſhed plates of metal during their expoſure to dry froſty winds, but alſo by direct experiments, in which the weight of ſolid pieces of ice was diminiſhed by expoſure in the ſame circumſtances. This evaporation or ſolution of ice in air takes place likewiſe in ſituations where there is no current of air, and even in air confined in cloſe veſſels. Sauſſure relates an experiment on this ſubject, which ſeems to be deſerving of notice. Into a glaſs globe, containing about a cubic foot and a quarter of air, he introduced a ſmall linen roller, which had been previouſly moiſtened with water, and congealed by expoſure to the cold. In this ſtate the roller weighed 25,003 grains. The temperature of the air in the room was kept at 2° 7-10ths below zero of Reaumur's ſcale. At the end of 24 minutes, a hygrometer placed in the globe plainly indicated an increaſe of humidity in the air; and this increaſe continued to go on for three hours. During this period, the roller loſt 1 78-100th grains in weight. See *Phil. Tranſ.* Vol. LXI. p. 326. Sauſſure's *Eſſais ſur l'Hygrometrie*, p. 186, 353.

[h] Mr. Kirwan has made ſome uſeful experiments on the expanſion of water by caloric at different degrees of temperature. He finds the weight of one cubic inch of water to be 253,182 grains Troy, or the weight of one cubic foot to be 1000 Avoirdupois ounces, when the temperature of the water is at 62° of Fahrenheit. See *Phil. Tranſ.* Vol. LXXV. p. 267.

[i] Mr. Watt found that water would diſtil readily in a vacuum, when of the temperature of 70° of Fahrenheit; and that in this caſe the combined caloric of the ſteam is not leſs than 1200 or 1300 degrees.

[k] It appears from the experiments of Scheele, Prieſtley, and others, that water abſorbs the oxygenous part of atmoſpheric air in preference to the azotic. When we expoſe water that has been deprived of its air to a given quantity of atmoſpherical air, this air is gradually diminiſhed in volume and purity, and the air abſorbed by the water is found to contain a greater proportion of oxygen gas than is naturally contained in an equal volume of the atmoſphere.

[l] Dr. Black firſt diſcovered that water, in paſſing from the liquid ſtate to that of an elaſtic fluid, abſorbs a quantity of caloric, which becomes *latent*, or which does not add to its temperature. He endeavoured to aſcertain the quantity of this caloric, by comparing the time neceſſary to raiſe the temperature of water a certain number of degrees with the time neceſſary for its evaporation in the ſame circumſtances. From his experiments, he computed it to be not leſs than 800° of Fahrenheit. By his directions, Dr. Irvine of Glaſgow tried to meaſure the quantity of caloric given out by ſteam during its condenſation in the refrigeratory of a common ſtill, and found it to be not leſs than 774°. Mr. Watt, who repeated with great care the experiments of theſe two philoſophers, eſtimates the quantity of caloric evolved during the condenſation of ſteam at 950 degrees. See *Phil. Tranſ.* 1784, p. 352.

[m] From an experiment made by Dr. Black and Mr. Watt, it was found that water in the form of ſteam occupies a ſpace 1400 times greater than in its ordinary liquid ſtate.

NOTES ON CHAPTER VII.

[n] Various attempts have at different times been made to meaſure the force of ſteam in different degrees of temperature. It is to be regretted, that the experiments made with this view have not been ſufficiently [illegible] afford any very extenſive ſcale. The following table, taken from the article *Steam*, in the 17th volume of the *Encyclopædia Britannica*, is the fulleſt [illegible] come within my notice. The reader will do well to conſult the whole article, as it contains much curious and original information, expreſſed [illegible] perſpicuity, elegance, and preciſion. Column firſt indicates the temperature to which the ſteam was ſubjected; column ſecond, the elaſticity of the ſteam at different degrees of temperature, as aſcertained by the aſcent (in inches) of the mercury in the barometrical tube.

Temperature.	*Elaſticity.*
32°	0,0
40	0,1
50	0,2
60	0,35
70	0,55
80	0,82
90	1,25
100	1,6
110	2,25
120	3,0
130	3,95
140	5,15
150	6,72
160	8,65
170	11,05
180	14,05
190	17,85
200	22,62
210	28,65
220	35,8
230	44,7
240	54,9
250	66,8
260	80,3
270	94,1
280	105,9

[o] The ſolubility of water in air is a fact highly deſerving of the attention of chemiſts, as this circumſtance may often occaſion conſiderable variations in the reſult of experiments which require great degrees of accuracy. The property of abſorbing water does not ſeem to be confined to atmoſpherical air, but to be common to moſt, if not all, bodies capable of aſſuming the elaſtic form. Our knowledge of this ſubject is, however, at preſent extremely limited; nor has it hitherto obtained that attention which its importance demands. Sauſſure (*Eſſais*, p. 231.) relates ſome experiments which prove the ſolubility of water in hydrogenous gas, and in carbonic acid gas; but he has omitted to mention the quantity theſe fluids are capable of diſſolving.

P iiij

In a former note, I remarked, that a cubic foot of atmoſpherical air under its ordinary preſſure is capable of holding in ſolution 11 grains of water. That eſtimate, taken from Sauſſure, is, it muſt be confeſſed, greatly below what ſome very reſpectable authors have made it. M. Lambert of Berlin aſſerts, that a cubic foot of air is capable of diſſolving 342 grains of water, which is nearly 0,43 of its whole weight. Mr. Kirwan alſo, from an experiment of his own, was led to conclude that a cubic foot of oxygenous gas may contain 96,251 grains. But there is reaſon to ſuſpect ſome fallacy in the experiments of theſe philoſophers. The eſtimate of Sauſſure is confirmed by ſome very accurate experiments of Guiton Morveau, detailed in the article *Air* of the *Encyclopedie Methodique*, p. 694. See *Kirwan on Phlogiſton*, p. 25, 27.

The circumſtances which moſt ſenſibly affect the ſolubility of water in air is the temperature and denſity of this fluid. Table I. will exhibit a view of the effects of temperature. Table II. the diminutions which take place in the diſſolving power of the air in conſequence of its rarefaction.

TABLE I. Of the Quantities of Water (in Grains) contained in a Cubic Foot of Air, at different Degrees of the Hygrometer and Thermometer.

Deg. of Hyg.	*Degrees of the Thermometer.*								
	— 10	— 5	0	+ 5	+ 10	+ 15	+ 20	+ 25	+ 30
40	0,8971	1.1067	1,3653	1,6843	2,0779	2,5634	3,1625	3,9016	4,8134
45	1,0676	1,3171	1,6248	2,0045	2,4729	2,9952	3,6952	4,5588	5.6242
50	1,2197	1,5047	1,8563	2,2900	2,8251	3,4852	4,2997	5,3045	6,5442
55	1.4116	1,7414	2,1483	2,6503	3,2696	4,0335	4,9761	6,1390	7.5737
60	1,6411	2,0246	2,4976	3,0590	3.7737	4,6554	5,7434	7,0856	8,7415
65	1,9204	2.3691	2,9226	3 6055	4,4480	5,4873	6,7697	8,3518	10,3036
70	2,2277	2,7482	3,3903	4,1824	5,1596	6.3651	7,8526	9,6878	11,9518
75	2,5215	3,1107	3,8375	4.7342	5,8404	7,2050	8,8888	10,9661	13.5289
80	2,8155	3,4734	4,2850	5,2862	6,5213	8,0450	9,9251	12,2446	15,1062
85	3,1095	3,8361	4.7324	5.8381	7,2022	8.8850	10,9614	13,5231	16,6834
90	3.4035	4,1987	5.1797	6,3900	7,8831	9,7250	11,9977	14,8016	18,2607
95	3.6946	4,5578	5,6227	6,9420	8,5640	10,5650	13,0340	16,0800	19,8379
98	3,8739	4,7790	5,8956	7,2731	8,9725	11,0690	13,6558	16,8472	20,7844

The ſcale of temperature in this table extends from 10° below zero to 30° above it in Reaumur's thermometer. The diviſions include only five degrees. In order that the reader may underſtand the degrees of the hygrometer, it is only neceſſary to remind him that Sauſſure employs the elongation of hair as the meaſure of the humidity of the air; and that the ſcale of his hygrometer, from the point of extreme dryneſs to that of extreme humidity, is divided into 100 degrees.

TABLE II. Of the Diminutions of the Diſſolving Power of the Air in different Degrees of Rarefaction.

Height of Barometer.		*Experiments of the Diminutions.*
Inches.	Lines.	
27		1,0000
23	7 1-half	0,9528
20	3	0,8899
16	10 1-half	9,8264
13	6	0,7629
10	1 1-half	0,6887
6	9	0,6230
3	4 1-half	0,4311
0	2 1-half	0,0485

Dr. Hutton of Edinburgh has made a very happy application of our knowledge of this ſubject to explain the production of rain. The diſſolving power of the air, he obſerves, muſt be either in the ſame ratio with the increaſe of temperature, or it muſt be in a leſs or in a greater ratio. If in the ſame ratio, the temperature of two equal portions of air, ſaturated with water, and mixed together, at different temperatures, will be found to be the arithmetical mean between the extreme temperatures; ſo there will be no precipitation of water. If in a leſs ratio, then it is evident that the mixtures of two portions of ſaturated air, at different temperatures, will produce no condenſation of water; but, on the contrary, will be capable of diſſolving an additional quantity of that fluid. If in a greater ratio, the mixture of the two ſaturated portions of air will produce a condenſation of water. It is this laſt caſe only that can be applied to explain the phenomena of vapour, and the formation of rain. According to this hypotheſis, therefore, whenever two ſtreams of air, or two contrary winds, of different temperatures, meet together, vapour or rain muſt neceſſarily be produced. For the numerous facts in proof of this ingenious theory, ſee *Diſſertations on Different Subjects of Natural Philoſophy.*

It may not be improper to remark that water exiſts in the air alſo in a viſible form, as in fogs, clouds, &c. Sauſſure calls theſe vapours *veſicular*, becauſe, like ſteam, they conſiſt of veſicles, or ſmall hollow ſpheres. In this ſtate there is no true combination, but merely a mixture of the particles of the water with the air. Sauſſure conjectures that it is the electrical fluid which ſurrounds theſe veſicles, and prevents them from diſſolving in the air, and forming with it a true combination. Theſe veſicles exiſt only in an atmoſphere ſaturated with vapour, and are ſaid to be from 1-380 to 1-190 of a line in diameter. *Eſſais ſur l'Hygrometrie*, p. 282.

[p] Count Rumford, lately Sir B. Thompſon, has made a ſingular diſcovery with reſpect to the non-conducting power of water for caloric. It had always been ſuppoſed that caloric was diffuſed in all directions through water in preciſely the ſame

manner as through ſolids of every kind. From a ſeries, however, of ingeniouſly contrived experiments, this philoſopher has been led to infer, that although the particles of water receive caloric from other bodies, and communicate it to them again, yet that among the particles of this fluid themſelves no communication of caloric whatever takes place. Caloric, according to this hypotheſis, is diffuſed in water ſolely by the motion of thoſe particles which have had their ſpecific gravity increaſed or diminiſhed in conſequence of a change in the ſtate of their temperature. This diffuſion, therefore, may be obſtructed, either by diminiſhing the fluidity of water, or by mixing with it ſubſtances that mechanically retard the motion of its particles. The effect of theſe cauſes is very fully evinced by a number of comparative experiments.

The bulb of a very ſenſible thermometer being placed in a proper apparatus, was furrounded ſucceſſively with equal quantities of pure water, a ſolution of ſtarch in water, ſtewed apples, and a mixture of water with eider down, and in this ſituation ſubjected to different degrees of temperature. The two following tables exhibit the reſults of a great variety of experiments.

	Time the Heat was in paſſing into the Thermometer.			
	Through a mixture of 2276 grains of water, and 192 grains of ſtarch.	Through a mixture of 2276 grains of water, and 192 grains of eider down.	Through ſtewed apples, containing 49-50 of pure water.	Through pure water.
	Seconds.	*Seconds.*	*Seconds.*	*Seconds.*
In heating the therm. from 32° to 40°	101	83	92	45
40° to 60°	72	55	71	35 1-half
80°	64	49	58 1-8th	32 1-half
100°	63	52	62 1-half	30
120°	74	57	69 1-half	36 1-half
140°	89	67	86	44
160°	115	93	117	61 1-half
180°	178	133	179	91 1-half
200°	453	360	362	220 1-half
Total time in heating the inſtrument from 32° to 200°	1109	949	1096 1-half	597
Time employed in heating the ther. from 80° to 160°	341	269	335	172

	Time the Heat was in paſſing out of the Thermometer.			
	Through the mixture of water and ſtarch.	Through the mixture of water and eider down.	Through ſtewed apples.	Through pure water.
	Seconds.	*Seconds.*	*Seconds.*	*Seconds.*
In cooling the therm. from 200° to 188°	69	68	77	41 1-half
180° to 160°	66	61	73 1-half	39 1-half
140°	74	72	83 1-half	43
120°	92	91	104	52 1-half
100°	119	120	138 1-half	73
80°	173	177	194	108 1-half
60°	283	279	314	202
40°	672	673	754	472
Total,	1548	1541	1749 1-half	1032
In cooling 80° from 160° to 80°	468	460	520	277

Accidentally perceiving the motion of ſome fine particles of duſt in a ſpirit of wine thermometer, this philoſopher was led to contrive the means of exhibiting to view thoſe internal motions of the particles of water which accompany every change in the ſtate of its temperature. To render this motion viſible, he mixed a ſmall quantity of amber, finely pulverized, with water, the ſpecific gravity of which had been raiſed to the ſame ſtandard by the addition of an alkaline ſalt. On plunging a glaſs globe, with a long cylindrical neck, containing this mixture, into boiling water, ſome very intereſting phenomena were obſerved.

"Two currents, in oppoſite directions, began at the ſame inſtant to move with "great celerity in the liquid in the cylindrical tube; the aſcending current occu- "pying the ſides of the tube, while that which moved downwards occupied its "axis.

"As the ſaline liquor grew warm, the velocity of theſe currents gradually di- "miniſhed; and at length, when the liquor had acquired the temperature of the "ſurrounding water in the jar, theſe motions ceaſed entirely.

"On taking the glaſs body out of the hot water, the internal motions of the li- "quor recommenced, but the currents had changed their directions; that which "occupied the axis of the tube being now the aſcending current.

"When the contents of the glaſs body had acquired the temperature of the air "of the room, theſe motions ceaſed; but they immediately recommenced on ex- "poſing the inſtrument to any change of temperature.

"The motions in oppoſite directions in the liquid in the tube were exceedingly "rapid on the ſudden application of a ſtrong heat, and afforded a very entertain- "ing ſight: But to a ſcientific obſerver they were much more than amuſing; "they detected nature, as it were, in the very act, in one of her moſt hidden ope- "rations, and rendered motions viſible in the midſt of an inviſible medium, which "never had been ſeen before, and which moſt probably had never been ſuſpect- "ed."

It ſeemed to follow as an obvious concluſion from theſe phenomena, that caloric cannot be propagated downwards in water while the particles of that fluid continue to be condenſed by cold; but the truth of ſo ſingular a concluſion required to be confirmed by ſtill more deciſive experiments.

A circular cake of ice, 3 1-half inches in thickneſs, and weighing 10 1-8th ounces, was introduced into a glaſs jar, containing 6 lbs. 1 1-4th ounces of water, at the temperature of 212° of Fahrenheit. The ice was entirely melted in 2 minutes and 58 ſeconds.

A ſimilar cake of ice was faſtened down to the bottom of the ſame jar, and water nearly boiling hot poured on it in this ſituation. A circular piece of paper had been previouſly interpoſed, to prevent the ſtream of water from impinging directly on the ice. In this experiment it was ſome time before any ſigns of melting could be perceived. After the thermometer had been in the jar one minute, the temperature was found to be 180°; after 12 minutes, the temperature 1 inch below the ſurface 170°; at the depth of 7 inches, or one inch above the ſurface of the ice, 169 1-20°; while at only 3-4ths of an inch lower, or 1-4th above the ſurface of the ice, its temperature was 40°. When an hour had elapſed, the temperature at the ſurface of the ice was

rature at the ſurface of the ice was	40°
1 inch above it,	80°
2 inches,	118°
3 inches,	128°
4 inches,	130°
7 inches,	131°
When two hours had elapſed, at the ſurface of the ice,	40°
1 inch,	76°
2 inches,	94°
3 inches,	106°
4 inches,	108°
6 inches,	108° 1-4th
7 inches,	108° 1-half

By now pouring off the hot water, it was found that 5 ounces 6 grains troy, of ice, had been melted. But in conformity with the hypotheſis, that water is a perfect nonconductor of heat; how could this quantity, ſmall as it was, have been melted? The manner in which our author endeavours to account for this is extremely ingenious. It appears, he obſerves, from the experiments of Sir C. Blagden, that the ſpecific gravity of the particles of water at the temperature of 32° muſt be conſiderably leſs than the ſpecific gravity of the ſame particles at the temperature of 40°. Now, as in pouring hot water on the ice, the temperature of the particles of the water in contact with the ice is immediately reduced to 32°; theſe particles muſt neceſſarily have a tendency to riſe and to occupy the place of the warmer, heavier, and conſequently deſcending particles. If this be in reality the way in which the ice is melted, then it becomes obvious, that caloric can only be propagated downwards in water, the temperature of which is reduced below 40°, for this is the point in which it begins to be expanded by every ſubſequent diminution of temperature. Reaſoning on theſe data, Count Rumford was led to adopt the following very remarkable concluſion, namely, that water, at the temperature of 40°, muſt be able to melt as much ice in any given time when ſtanding on its ſurface, as an equal volume of water at the temperature of 212°. This concluſion was ſoon verified by experiment. Uſing every precaution to avoid inaccuracy in the calculations, it appeared that not more than 152 grains of ice were melted by the boiling water during the ſpace of the firſt 10 minutes. The quantity of ice melted by water at the temperature of 40° in an equal ſpace of time, amounted to no leſs than 222 grains. "This fact," adds our author, "will, I flatter

" myſelf, be conſidered as affording the moſt unqueſtionable proof that could " well be imagined, that water is a perfect nonconductor of heat, and that heat " is propagated in it only in conſequence of the motions which the heat occaſions " in the inſulated and ſolitary particles of that fluid." See *Count Rumford's Experimental Eſſays*, No. VII. *paſſim.*

We cannot help thinking this concluſion by far too general. The experiments related undoubtedly prove that caloric is communicated very ſlowly from one particle of water to another; but it would require more numerous and diverſified experiments to eſtabliſh the fact that no communication whatever occurs.

[q] As the truth of the compoſition and decompoſition of water has been often doubted, and is even ſtill diſbelieved by ſome of the older chemiſts, it may not be improper to bring into one point of view the nature and extent of the evidence by which this important fact is ſupported.

Chemical philoſophers had at different times obſerved, that moiſture was produced by the combuſtion of inflammable gas; but none of them ſeem to have formed any opinion with reſpect to the ſource from which this moiſture is derived. See *Appendix to Macquer's Dictionary, article* Inflammable Gas. *Prieſtley on Air*, firſt edit. Vol. V. p. 395.

It was in the ſummer of 1781 that Mr. Cavendiſh firſt burned, in a convenient apparatus, 500,000 grain meaſures of inflammable air, with 2 1-half times the quantity of atmoſpherical air. " By this means (See *Phil. Tranſ.* Vol. LXXIV. " p. 129.) upwards of 135 grains of water were condenſed in the cylinder, which " had no taſte nor ſmell, and which left no ſenſible ſediment when evaporated " to dryneſs, neither did it yield any pungent ſmell during evaporation; in " ſhort, it ſeemed to be pure water." Mr. Cavendiſh, in repeating this experiment, fired, by means of the electric ſpark, 19,500 grain meaſures of oxygen, with 37,000 grain meaſures of hydrogen gas; about 2950 grain meaſures were conſumed, and 30 grains of a liquor condenſed in the globe, which was ſenſibly acid to the taſte. Saturated with potaſh, this liquor afforded nearly 2 grains of nitre. When the proportion of the hydrogen gas was ſufficiently increaſed, the condenſed liquor was not at all acid, but ſeemed to be pure water.

From a preconceived theory, Lavoiſier had expected that an acid would reſult from the combuſtion of oxygen with hydrogen gas; and accordingly, in the winter of 1781-2, he made, in company with M. Gengembre, an experiment to aſcertain this point. Lime water was agitated in the veſſels in which theſe gaſes had been inflamed, but no marks of an acid could be detected. Lavoiſier expreſſes his ſurpriſe at the reſult of this experiment, as, both from former experiments, and from analogy, he had been led to expect, with confidence, the preſence of an acid. See *Mem. de l'Acad.* 1781, p. 470.

It was not till the 24th of June 1783, that Lavoiſier, with De la Place, made that famous experiment, which left no longer any room to doubt of the nature and compoſition of water. Lavoiſier, in the account which he gives of that experiment, very candidly acknowledges that Dr. Blagden, who was preſent when it was made, had mentioned to him the reſult which Mr. Cavendiſh had formerly obtained. " But (Mr. Cavendiſh remarks) ſo far was Lavoiſier from thinking any " ſuch opinion warranted, that till he was prevailed on to repeat the experiment " himſelf, he found ſome difficulty in believing that nearly the whole of the two " airs could be converted into water."

In the experiment made by Lavoiſier and De la Place, about 5 drachms of water were obtained, which ſeemed to be free from every kind of admixture. It correſponded very exactly in weight to the two gaſes which had diſappeared, and afforded reaſon to conclude that 100 grains of water conſiſt of 85 grains of oxygen united to 15 grains of hydrogen. See *Mem. de l'Acad.* 1781, p. 468.

An experiment made about the ſame time by Monge is, if poſſible, ſtill more accurate. He inflamed, by means of the electric ſpark, 14591-144 pints of hydrogen, with 749-16 of oxygen gas. The ſum of the weight of the two gaſes was 3 ounces 6 drachms 27,56 grains. Three ounces 2 drachms 45 grains of water were obtained, which had a ſlightly acidulous taſte. This acidity, Monge ſeems to think, might be attributed to a ſmall portion of the ſulphuric acid, which the hydrogen gas had carried over into the receiver. The air remaining after the experiment, amounting to 2 drachms 56,91 grains, conſiſted of a mixture of carbonic acid, oxygen, hydrogen, and azotic gaſes. There was therefore in this experiment, a loſs of not more than 1 drachm 26,55 grains. See *Mem. de l'Acad.* 1783, p. 78.

In the ſummer of 1788, M. Le Fevre de Giheau, obtained 2 pounds 3 ounces 33 grains of water from the combuſtion of oxygen and hydrogen gaſes. The oxygen gas was procured from the oxyd of manganeſe, and the hydrogen from a mixture of diluted ſulphuric acid, and filings of iron. Previous to combuſtion great pains were taken to free the gaſes from every adventitious ſubſtance. The weight of the water obtained, was only 31 grains leſs than the total weight of the gaſes conſumed. This water had an acid taſte; gave a red colour to the tincture of turnſole, and rendered lime water turbid. Solutions of the nitrate of ſilver and barytes produced no precipitation; from which it is evident, that it contained neither ſulphuric nor muriatic acid. By adding potaſh to the water, it was found to contain 1-750th part of its weight of acid, or 27 1-half grains. This acid was the nitric. See *Journ. de Phyſ.* 1788, p. 457.

Meſſrs. Fourcroy, Seguin, and Vauquelin, repeated the experiment of Lavoiſier with very great care. The oxygen gas was obtained from oxygenated muriat of potaſh, and contained about 3 cubic inches in the 100 of azotic gas. The hydrogen gas was procured from a ſolution of zinc in diluted ſulphuric acid. The combuſtion was carried on more ſlowly than in any of the preceding experiments, and 12 ounces 4 drachms 45 grains of water were obtained. The weight of the gaſes conſumed amounted to 12 ounces 4 drachms 49 grains; ſo that there was in all a loſs of only 4 grains during the experiment. The water ſeemed to be perfectly pure, as no change could be effected by the uſe of re-agents. Its ſpecific gravity was the ſame with that of diſtilled water. See *Annal. de Chem.* Tom. VII. p. 257. Tom. VIII. p. 230. Tom. IX. p. 30.

The combuſtion of oxygen with hydrogen gas was lately performed in an improved apparatus, by Mr. Higgins of London. The ſum of the weights of the two gaſes conſumed, was 489 grains. The water produced from the combuſtion of theſe gaſes, weighed 487 grains; it ſeemed to be pure, and contained no ſenſible mark of acidity. See *Minutes of a Society for Phil. Exp.* p. 175.

It appears from the experiments we have now related, that though the water ariſing from the combuſtion of oxygen with hydrogen gas generally contains an acid, yet that this is by no means either a neceſſary or a conſtant occurrence. This acid is of different kinds, and in the greater number of caſes it ſeems eaſy to account for its production. Moſt frequently it was the nitric; oxygen gas, from whatever ſubſtance it is procured, is generally found to contain a greater or leſs proportion of azotic gas; and from the experiments of Mr. Cavendiſh it is proved, that nitric acid may be produced by paſſing the electric ſpark through a mixture of theſe two gaſes. When azotic gaſs, therefore, is preſent in a large quantity, or when there happens to be a deficiency of hydrogen gas, nitric acid will neceſſarily be formed. But neither in the experiments of Mr. Cavendiſh, nor in thoſe of Van Marum, was any acid produced when the combuſtion of the two gaſes was conducted ſlowly, or when the hydrogen gas employed was in a ſufficiently large proportion. See *Nachträge Von Scherer*, ſ. 462.

The ſulphuric acid which was ſometimes obtained, may have been derived from a ſmall quantity of this ſubſtance which had paſſed over undecompoſed into the receiver, along with the hydrogen gas, or rather from the decompoſition of a ſmall portion of ſulphuric acid, and the combination of its ſulphur with the hydrogen gas. The great attraction which theſe ſubſtances have for one another, and the difficulty we find in ſeparating them, renders it extremely probable that this is the way in which the ſulphuric acid was formed. In only one inſtance, ſo far as I can learn, has it been ſaid, that the muriatic acid was produced; but as we are entirely ignorant of the compoſition of this ſubſtance, it muſt remain for future experimenters, ſhould the circumſtance ever again occur, to diſcover the ſource from which this acid had been derived.

It is almoſt ſuperfluous to remark, that the proportion of the acid to the water was uniformly ſo ſmall, as not to influence, in any degree, the accuracy of the concluſions to which theſe experiments inevitably lead.

We have another proof of the formation of water in the reduction of metallic oxyds. Theſe are now univerſally allowed to conſiſt of a metal united to a greater or leſs portion of oxygen. It is to Dr. Prieſtley we owe the intereſting diſcovery, that theſe oxyds, confined in cloſe veſſels, with hydrogen gas, and expoſed to the focus of a burning-glaſs, are reſtored to the ſtate of pure metal. The hydrogen gas diſappears during this reduction, nor is any oxygen gas evolved in a ſenſible form. If the experiment be made over mercury, vapours are obſerved, which gradually condenſe into water. Dr. Prieſtley tried to aſcertain the quantity of hydrogen gas which diſappeared in the reduction of the different metallic oxyds. According to his experiments, it was nearly in the following proportion: An ounce of oxyd of iron, required 890 ounce meaſures of this gas for its reduction; an ounce of copper, from 403 to 909, according to the ſtate of the oxyd; an ounce of tin 377, and of biſmuth 185. The oxyd of ſilver alſo abſorbed hydrogen gas, but in a proportion that could not be aſcertained. No perceptible reduction took place in the oxyds of manganeſe, zinc, arſenic, and antimony. Alkaline gas, which contains much hydrogen gas in a looſe ſtate, was found to anſwer equally well for the reduction of theſe bodies. Dr. Prieſtley expoſed the oxyds ſucceſſively to the focus of the burning-glaſs, in carbonic acid; in nitrous gas; in azotic gas; fluoric acid gas; oxygen gas, and atmoſpherical air; but in none of theſe fluids was any particle of the oxyd reduced. That philoſopher endeavours to explain theſe phenomena, by ſuppoſing, that the hydrogen is abſorbed by the oxyd during its reduction, and enters as a conſtituent part into the formation of the metal. But this hypotheſis is obviouſly inadmiſſible: 1ſt, Becauſe it does not enable us to explain the loſs of weight in the metallic oxyd during its reduction: And, 2dly, Becauſe, if the experiment be performed over mercury, and the water which is formed carefully collected, it will be found to correſpond exactly in weight to the weight of the hydrogen gas which has diſappeared, added to that which the metallic body has loſt in the experiment. See *Experiments and Obſervations*, London, 1790. Vol. I. p. 248. *Annal. de Chem.* Tom. I. p. 106.

Dr. Prieſtley ſeems alſo to have ſucceeded in decompoſing ſome of the acids, by treating them in the ſame manner with hydrogen or alkaline gas. He expoſed a quantity of phoſphoric acid, in hydrogen gas, to the focus of a burning-glaſs, the volume of the gas was diminiſhed about 1-4th, and the inſide of the veſſel covered with an orange coloured ſubſtance, which had a ſtrong ſmell of phoſphorus.

The introduction of the vapour of boiling nitrous acid, into contact with hydrogen gas, is ſaid to have been followed with the immediate formation of azotic gas; but this experiment ſeems to have been inaccurately performed.

Sulphuric acid, expoſed to the concentrated rays of the ſun, in a receiver filled with hydrogen gas, was gradually decompoſed. At the end of the experiment, the inſide of the receiver was covered with a whitiſh incruſtation, which, when put on a piece of hot iron, exhibited the genuine blue flame, as well as the peculiar ſmell of ſulphur. See *Obſerv. and Exp.* Vol. I. p. 262.

The compoſition of water had ſcarcely been diſcovered, when it was ſuſpected that its decompoſition might alſo be effected.

Bergman had obſerved in his analyſis of iron, that the filings of this metal were converted into a martial æthiops, by diſtilled water alone, while at the ſame time a great quantity of inflammable air was gradually diſengaged. Fontana alſo had obtained inflammable air, in extinguiſhing burning charcoal by immerſion in this fluid; and Meſſrs. Haſſenfratz, Stoutz, and d'Hellancourt had collected inflammable gas by immerſing red hot iron under bell glaſſes filled with, and inverted over water.

From theſe facts, and from the experiment he made in company with Lavoiſier, De la Place was led to infer, that the inflammable gas obtained during the ſolution of iron and zinc, in diluted, ſulphuric, and muriatic acids, was derived ſolely from the decompoſition of the water. His opinion is ſtated with admirable preciſion inpage 476 *of the Mem. de l'Acad.* for 1781, and has ſince been confirmed by innumerable experiments.

It is but juſtice to add, that the ſame inference, reſpecting the decompoſition of water, had been made by Mr. Watt, and communicated by him in a letter to Dr. Prieſtley, dated April 26. 1783. See *Phil. Tranſ.* Vol. LXXIV. p. 330.

On placing iron filings in pure diſtilled water, Lavoiſier obſerved, that theſe two ſubſtances exerted a mutual action on each other. A conſiderable quantity of hydrogen gas was diſengaged, and at the end of ſome months the iron filings were converted into a black powder, reſembling æthiops mineral, and had acquired an additional weight of 25 per cent.

Lavoiſier and M. Meuſnier produced a ſimilar effect by varying the experiment. They introduced into an iron tube ſome thick iron wire, flattened by hammering, and placed the tube, in an oblique direction, in a furnace, which was heated red hot. The water was permitted to enter the upper extremity, drop by drop; and immediately pure hydrogen gas, in great quantity, iſſued out at the lower extremity of the tube. The wire, and inſide of the tube, at the end of the experiment, were found oxydated, or, in other words, reduced exactly to the ſame ſtate with iron which has been burned in oxygen gas. The tube and wire were weighed before, and after the experiment; and it was found, that the additional weight they had acquired, when added to that of the hydrogen gas which had been diſengaged, correſponded moſt accurately with the total weight of the water which had diſappeared. The hydrogen gas evolved in this experiment, was afterwards burned with a quantity of oxygen gas, equal to the weight which the iron in the tube had acquired; and the product from this combuſtion amounted to about 6 ounces of water. See *Mem. de l'Acad.* 1781.

Dr. Prieſtley had often obſerved the ſame appearances, and had made a variety of intereſting experiments on the production of hydrogen gas, by making the vapour of boiling water paſs through iron filings heated red hot; but, with his uſual infelicity in accounting for chemical phenomena, the Doctor ſuppoſed that the hydrogen came from the iron, and not from the water. See *Exp. and Obſ.* Vol. I. p. 288 to 301. *Kirwan on Phlogiſton*, laſt edit. p. 56.

Le Fevre de Gineau repeated the experiment of Lavoiſier; but inſtead of an iron, he employed a porcelain tube. The reſults he obtained were ſo accurately the ſame, that he was able to fix 15,7 grains as the proportion of hydrogen contained in 100 grains of water. See *Journ. de Phyſ.* Dec. 1788.

In every inſtance in which this experiment has been carefully made, the ſame unvarying reſults have been conſtantly obtained.

Von Hauch, of Copenhagen, introduced a quantity of zinc, in ſmall pieces, into a porcelain tube. After the tube had been kept for ſome time in a red heat, the vapour of boiling water was made to paſs through it. The products ariſing from this experiment were pure hydrogen gas, and the oxyd, or what is uſually termed the flowers of zinc. See *Grundzüge Von Scherer*, ſ. 202.

Count Rumford diſcovered, that when aqueous vapour is brought into contact with mercury in the ſtate of vapour, the mercury is oxydated, and a portion of red precipitate formed. See *Nachträge Von Scherer*, ſ. 470.

In the experiments of Hauch, formerly quoted, it was found, that aqueous vapour, conducted through gold, ſilver, or copper tubes, which were kept in a red heat, did not undergo any change; nor was any hydrogen gas evolved, the affinity of the oxygen for the hydrogen being greater than for any of theſe metals.

The decompoſition of water takes place alſo, as we have already remarked, in the ſolution of metals in diluted ſulphuric or muriatic acids. Morveau, after pouring 3 ounces of concentrated ſulphuric acid on 1 1-half ounce of iron nails, expoſed them to a ſtrong heat. About 3 cubic inches of atmoſpheric air paſſed over into the receiver; and the water which this veſſel contained was impregnated with ſulphureous acid. To the ſame ſubſtances he added 9 ounces of water, and placed the mixture in a heat of a low temperature. Not leſs than 754 cubic inches of hydrogen gas were evolved. The metal was converted into an oxyd. On ſaturating the acid remaining after the experiment with an alkali, it was found to require the ſame quantity it would have done previous to the experiment. A more direct proof cannot be conceived, that the water, not the acid, is the ſource from which the hydrogen gas was derived. See *Grundzüge*, ſ. 196.

Dr. Fordyce, of London, made a no leſs intereſting experiment. He ſaturated 1000 grains of diluted ſulphuric acid with alkali, and obtained, by evaporation, 978 grains of dry ſulphate of potaſh. He then diſſolved 164 grains of zinc in an equal quantity of the ſame acid, and precipitated the metal from its ſolution by the addition of an alkali. By evaporation, 976 1-16th grains of dry ſulphat of potaſh were obtained, being not quite two grains leſs than when the acid was added directly to the alkali, without the intervention of the zinc. The oxyd which had been precipitated, weighed 220 grains. It is needleſs to remark, this additional weight could neither be derived from the acid nor the alkali: Added to the weight of the hydrogen gas evolved, it correſponded exactly with the weight of the water which diſappeared during the experiment. See *Phil. Tranſ.* 1792, p. 374.

By extinguiſhing lighted charcoal in water, Fontana had obſerved, that a mixture of carbonic acid and hydrogen gas was produced. The ſame phenomenon was obſerved by M. Achard, of Berlin. See *Grundzüge Von Scherer*, ſ. 203.

Lavoiſier and M. Meuſnier conducted aqueous vapour through charcoal, which, in order to free it from air or moiſture, had been kept for two hours in a red heat.

Hydrogen gas, containing about 1-4th of its volume of carbonic acid gas, was obtained. The charcoal diſappeared. The weight of the two gaſes correſponded exactly to the ſum of the weights of the aqueous vapour and charcoal which had been conſumed. See *Mem. de l'Acad.* 1781, p. 279.

This experiment was repeated by Dr. Prieſtley, and ſimilar reſults obtained. See *Obſerv. and Exp.* Vol. I. p. 282.

Phoſphorus does not immediately decompoſe water; but it can be made to produce this effect, by the addition of another ſubſtance. Hauch, in diſtilling 200 grains of phoſphorus with 500 grains of cauſtic alkali, or quicklime, (in a pure ſilver retort), to which a little water had been added, obtained phoſphorated hydrogen gas. There remained in the retort a phoſphat of alkali, or lime. It is obvious, that, in this experiment, the water is the only ſubſtance from which the oxygen of the acid could poſſibly have been obtained. See *Grundzüge Von Scherer*, ſ. 207.

Dr. Prieſtley ſays he obtained hydrogen gas, in tranſmitting ſteam over a quantity of ſulphur, which was melted in a hot earthen tube. It ſeemed to be equally pure with that obtained from the ſolution of iron in diluted ſulphuric acid. *Exp. and Obſer.* Vol. I. p. 203.

Could any more facts be required to render this account of the compoſition and decompoſition of water completely ſatisfactory, we ſhall find them in the ſingular effects produced by the paſſage of the electric ſpark through this fluid.

Meſſrs. Van Trotzwick, Deiman, and Cuthbertſon, introduced a gold wire into each extremity of a glaſs tube, 1-8th of an inch in diameter, and 12 inches in length. One end of this tube was ſealed hermetically, and the extremities of the wires in the tube fixed at the diſtance of 5-8ths of an inch from each other. After filling this tube with, and inverting it over water, they brought the wires into connection with an electrical machine. Every time an electric diſcharge was ſent through the water, ſmall air bubbles were ſeen riſing to the upper part of the tube. When the column of air produced by a continued ſucceſſion of diſcharges had increaſed ſo as to come into contact with the inferior extremity of the upper wire, a very remarkable phenomenon occurred. The next diſcharge produced a ſudden exploſion, inſtead of adding to the air which had been evolved. When the water contained atmoſpherical air, the reſidue, after inflammation, was always greater than when the water had been previouſly deprived of this ſubſtance by diſtillation. The reſidue, in ſome of their experiments, did not exceed 1-80th of the whole. This experiment is the more valuable, as it at once affords a ſynthetical, as well as analytical proof of the nature and formation of water. See *Journ. de Phyſ.* 1789, p. 369.

Van Marum repeated this experiment, with conſiderable alterations. Inſtead of gold, he employed a wire of platina, and ſupported the water on which he operated on a column of mercury. Gas was evolved, as in the former experiment; but it did not inflame by the electric ſpark. On adding to it, however, a little oxygen gas, or atmoſpherical air, inflammation was inſtantly produced. Hydrogen, therefore, one of the conſtituent parts of water, muſt neceſſarily have been evolved. Van Marum thinks that the other part, oxygen, had united with the mercury. See *Nachträge Von Scherer*, ſ. 471. See alſo *a Letter on this Subject, by Meſſrs. Silveſter and Chappe. Annal. de Chem.* Tom. VI. p. 121.

Mr. Cuthbertſon performed this experiment with water which had been boiled, and deprived of its air under the exhauſted receiver of an air-pump. When the air extricated from the water was placed between the extremities of the two wires, and a ſpark paſſed through the tube, it inſtantly diſappeared, leaving behind it only about 1-40th of reſidue. After the experiment, re-agents did not produce any ſenſible effect on the water in the tube. See *Tranſlation of the Chemical Nomenclature, by Dr. Pearſon*, p. 56.

To the experiments already enumerated, Dr. Pearſon, of London, has lately made ſome very accurate and intereſting additions.

He examined the air extricated from water by electric diſcharges, and found it to conſiſt of a mixture of oxygen and hydrogen gas. In the early part of the experiment, this air always contained a greater or leſs portion of the atmoſpherical air, uſually diſſolved in water, and which could not be completely ſeparated, either by boiling, or by the air-pump. When the diſcharges, however, had been continued for ſome time, pure oxygen and hydrogen gas alone were obtained. A partial combuſtion was obſerved to take place, even before the column of air in the tube had deſcended ſo low as the inferior extremity of the upper wire. This, which ſometimes amounted to nearly 1-5th of the whole, Dr. Pearſon ſeems to think, might be occaſioned by the kindling of the air bubbles in their aſcent through the water. Complete combuſtion could alſo be produced, by applying, during the paſſage of the electric ſpark, the points of a pair of compaſſes to the oppoſite ſides of the tube. It was of no conſequence to the ſucceſs of this experiment, whether the air in the tube was that extracted from water, or conſiſted of an artificial mixture of oxygen and hydrogen gas. See *Phil. Tranſ.* 1797, p. 142.

In reviewing theſe experiments, the reader muſt already have anticipated the obvious concluſion, that water is not a ſimple, but a compound body, conſiſting of nearly 85-100dth parts of oxygen, united to 15-100dth of hydrogen. A variety of objections have at different times been made to the validity of this concluſion, and to the accuracy of the experiments on which it is founded; but as theſe objections ſeem to be derived chiefly from the pre-conceived notions and long-eſtabliſhed opinions of thoſe who urge them, it will now be unneceſſary, I preſume, to enter into any formal or tedious diſcuſſion of their merits.

It has been ſaid, *that the water ariſing from the apparent combination of hydrogen with oxygen gas was merely depoſited from theſe fluids, and not generated during the proceſs of combuſtion.*—The anſwer to this is obvious. The weight of the water depoſited during this proceſs correſponds exactly with the ſum of the weights of the two gaſes conſumed. But 100 grains of gas cannot ſurely retain, diſſolved in it, 100 grains of water. Either, then, we muſt admit, that oxygen gas, hydrogen, and water, are one and the ſame ſubſtance, exiſting in three different ſtates, or acknowledge the validity of the proofs which demonſtrate the compoſition of water.

It has alſo been repeatedly maintained, *that, in every inſtance in which water has been ſuppoſed to be decompoſed, the hydrogen was derived from the inflammable body, and not from the decompoſition of water.*—Unfortunately for this objection, in every inſtance in which hydrogen is evolved, the inflammable body acquires an additional weight. This weight, added to that of the hydrogen gas, correſponds exactly in weight with the water which diſappears.

No inference can reaſonably be deduced from the great quantity of gas obtained in the ſuppoſed decompoſition of water, as this ſubſtance is capable of being converted by heat wholly into a permanently elaſtic fluid.—This objection, of late ſo ſtrongly urged by Dr. Prieſtley, will not have much influence on the minds of thoſe who will take the trouble to compare the experiments on which it is founded; with thoſe which have been ſo amply related. In diſtilling water in cloſe veſſels, the Doctor found that air continued to be extricated from it till the whole of the water had paſſed over into the receiver. This air, which was purer than common air, amounted only to between 1-20th and 1-30th of the bulk of the water. From 25 ounces of water, diſtilled in this manner, he obtained 2 ounce meaſures of air. The ſame extrication of air was produced, by expoſing water over mercury, in tubes, cloſed at one end, to a ſtrong degree of heat. A large bubble of air was collected, which continued to be permanent after the fire was withdrawn. In the courſe of a day or two, this air never failed to be abſorbed by the water in the tube. From theſe experiments, the Doctor concludes, that water is not only convertible into air, but that it may be conſidered as the baſis of every elaſtic fluid. By the experiments with the electric ſpark, it has been proved, that it is impoſſible to ſeparate all the air which water contains, merely by boiling, or by expoſure to the exhauſted receiver of an air-pump. The ſmallneſs of the quantity of air obtained, affords, therefore, a convincing proof, that this was the true ſource of that which Dr. Prieſtley procured. We can ſcarcely doubt of this, after being informed, that, in the courſe of a day or two, "*this air was again all abſorbed by the water.*" In all, it did not amount to more than 1-6000dth part of the water! Such are the experiments by which the facts which eſtabliſh the compoſition of water have been combated! It is unneceſſary to make any further remarks on the remaining part of the Doctor's eſſay, or the ſingular concluſions he has been led to form, as they ſtand in direct oppoſition to all accurate experiment, and legitimate inference reſpecting the nature and formation of elaſtic fluids. See *Experiments on the Generation of Air from Water*, p. 23.

Hauch, of Copenhagen, has tried the diſtillation of water in tubes formed of a great variety of ſubſtances; and in all his experiments, whenever the water was pure, and the tubes impervious, not a particle of permanently elaſtic gas was produced.

Some German chemiſts, in diſtilling water through earthen tubes, obtained, along with the water, a quantity of azotic gas. From this occurrence, they were led to infer, that this ſubſtance muſt neceſſarily be one of the conſtituent parts of water. The accurate reſearches of Hauch have detected the fallacy of theſe experiments. The earthen tubes appear to be permeable in a high degree of heat, both to air and water; for, when the experiment was performed in glaſs or porcelain veſſels, no azotic gas ever was formed. See *Grundzüge Von Scherer*, ſ. 226.

CHAPTER VIII.

CONCERNING EARTH IN GENERAL.

THE ancient philoſophers entertained an opinion, that there exiſts one ſimple ſubſtance, the principle of hardneſs, dryneſs, weight, and fixity in bodies, conſtituting the baſe of all ſolid bodies, to which they gave the name of earth. This opinion, founded purely on abſtract philoſophical notions, has been conſtantly taught in the ſchools, and is ſtill admitted by ſome of the learned. Paracelſus, as we have ſeen, denominated all the reſidues of analyſes, earth; but chemiſts, by the advice and example of Glauber, having examined thoſe reſidues, found they were far from being pure earthy ſubſtances. Boerhaave, who, with ſome limitation, had adopted the opinion of Paracelſus, obſerved, that after all analyſes, there remained a dry, inſipid, heavy, colourleſs matter, poſſeſſing all the properties of an earth. But when the proper methods of chemical examination are applied to theſe matters, it is found that they differ greatly from each other, and that one and the ſame denomination cannot with propriety be applied to them all.

Beccher admitted three kinds of earth, as has been mentioned, in ſpeaking of principles; namely, the vitrifiable, the inflammable, and the mercurial earth. Stahl regarded the firſt of theſe as the true earthy principle; and Macquer joins him in thinking, that the vitrifiable earth ought to be conſidered as the moſt pure and ſimple.

To arrive at a proper determination on this ſubject, let us conſider what are the properties which chemiſts univerſally admit, as diſtinguiſhing the element of earth. We find ſix; namely, weight, hardneſs, inſipidity, fixity, infuſibility, and immutability. But all theſe properties are found in the earth of quartz, rock cryſtal, and vitrifiable ſtones in general, as well as in that of clays. If, therefore, ſeveral matters, very different from each other, have all the properties attributed in general to the element called earth, ought we to regard them as ſo many ſimple and primitive earths, or ought we to adopt the opinion of Stahl and Macquer, who, obſerving the properties of earth moſt evidently in the vitrifiable, have thought proper to eſteem it as the primitive earth, and the others as modifications produced by its entering into different compounds?

Seducing as this hypotheſis may be, and however great the confidence we might place in the opinion of ſuch eminent chemiſts, we cannot think it proper to reckon the vitrifiable earth the primitive baſe of the others. 1. Becauſe this earth is not equally pure in all the ſtones, wherein Macquer and Stahl himſelf have admitted it; for example, in quartz, rock cryſtal, and flints. 2. Becauſe we find all the properties of terreſtrial ſubſtances in ſeveral matters which differ from vitrifiable earth, only in the earthy characters being not in ſo marked a degree. 3. Becauſe it is not at all proved, that vitrifiable earth is the baſe of all ſolid matters, and all earths, as ſome chemiſts have thought.

This, therefore, is the opinion we think proper to be adopted on this head.

Nature preſents ſeveral ſubſtances to our obſervation, which have all the properties of earths. We cannot aſcertain which is the ſimpleſt among them, becauſe they all ſeem to be equally ſo, as far as experiments have determined; and even if it were diſcovered that one of them were ſimpler than the reſt, it could not be concluded to be the elementary earth, till it was ſhown to be the baſis of other earths, and the cauſe of coheſion and ſolidity in various compounds. We ought therefore, without deciding which is properly ſpeaking the element, to admit of different kinds of earths, and endeavour to obtain ſuch a knowledge of their properties, as will ſerve to diſtinguiſh them whenever they are met with in chemical analyſes.

Chemiſts have long admitted ſeveral kinds of earthy matters; but their firſt diviſions were vicious in many reſpects, becauſe the characters they were founded on were neither ſufficiently certain, nor numerous. Such, for example, is the diſtinction of earths into mineral, vegetable, and animal earths: For, though it is true, that the fixed reſidues, from the ultimate analyſis of vegetables, after lixiviation, are for the moſt part without ſmell, taſte, or ſolubility, theſe properties are not ſufficient to juſtify the claſſing them with earths, becauſe they are neither unalterable, infuſible, nor ſimple. The ſubſtance which forms the dry and ſolid baſe of the bones of animals, and is ſtill called by the name of earth, from its dryneſs, inſipidity, and inſolubility, has been known for ſome years to be a true ſaline ſubſtance, as we ſhall ſhow in our chemical hiſtory of the animal kingdom; and it may with great probability be conjectured, that the inſipid and inſoluble reſidues, after the laſt analyſis of other animal matters, are of the ſame nature as the reſidual matter of bones. The name of *metallic earths*, given to the oxyds of ſeveral metals, from the dryneſs, inſipidity, and inſolubility of ſome of them, does not agree with their other properties; for they are in general fuſible, and are all known to be compounded, as will hereafter be ſhown.

Mineralogiſts, who have treated of the hiſtory of earths, have paid a greater attention to accuracy and preciſion in their claſſification than chemiſts, who have attended to them only in ſuch a general way as they thought might ſerve to advance the theory of the ſcience they cultivated. The greateſt number of modern naturaliſts, who have claſſed theſe matters, have adopted characters founded on theſe chemical properties, and, by that means, given much perſpicuity to the natural hiſtory of the mineral kingdom. Such are Meſſrs. Wallerius, Cronſtedt, and Monnet, who have compoſed complete ſyſtems of mineralogy on this principle. No chemiſt has made a greater number of reſearches into the nature of ſtones and earths than Pott, who has given a methodical arrangement of theſe bodies, founded on the reſults of his own experiments. Much praiſe and gratitude is due from the public to M. d'Arcet for his continued labours, and to Meſſrs. Bergman and Bayen for their analyſes of many earthy ſubſtances. We ſhall not attempt to exhibit or compare the different ſyſtems of theſe authors, as it is not our preſent intention to write the natural hiſtory of earthy ſubſtances; but ſhall only avail ourſelves of their labours, to determine how many different kinds of earths there are, chemically conſidered, and what are the diſtinctive characters of each.

Before we enter on this ſubject, we muſt obſerve that it is proper to conſider ſtones and earths as conſtituting the ſame claſs, becauſe they are, in fact, nothing more than one and the ſame ſubſtance in a different ſtate of aggregation. Grit-ſtone, for example, is nothing more than ſand united by the force of aggregation; and ſand conſiſts of grit-ſtone, whoſe integrant parts are diſunited: both ſubſtances having preciſely the ſame chemical properties.

M. Pott has divided earths and ſtones into four claſſes; the vitrifiable, the argillaceous, the calcareous, and the gypſeous.

Subſequent diſcoveries have ſhown, that the ſubſtances formerly diſtinguiſhed by the name of calcareous earth, are true neutral ſalts; and gypſeous ſtones are alſo known to be ſaline ſubſtances. Among the four claſſes of ſtones admitted by Pott, there are only two which belong really to this genus.

Dr. Black, whoſe name diſtinguiſhes one of the greateſt periods of the improvement of chemiſtry, having examined with much care the baſe of the Epſom ſalt, has proved that it conſiſts of a peculiar ſubſtance, which he called magneſia, and placed among the earths. All the chemiſts have aſſented to his diſcovery.

M. Bergman has diſcovered in the marmor metallicum, or heavy ſpar, a peculiar earth, which he has called terra ponderoſa, or ponderous earth, which we call barytes.

We think we ought to diſtinguiſh theſe two ſubſtances from earths properly ſo called, in conſequence of reaſons which we ſhall give in the following chapters.

From various conſiderations, we think that no bodies ſhould be admitted as true earths, but ſuch as are perfectly inſipid, inſoluble, and infuſible; and that we ought to diſtinguiſh ſuch as poſſeſs theſe properties by the chemical phenomena they exhibit. We therefore admit of but two kinds of pure earths, which are equally ſimple and elementary.

The firſt is, that which conſtitutes the baſe of rock cryſtal, quartz, grit-ſtone, flints, and all hard ſtones that ſtrike fire with ſteel. Its chemical character is, that it is unalterable by the ſtrongeſt fire, neither loſing its hardneſs, tranſparency, nor other properties, by any heat that art can produce. It is called vitrifiable earth, becauſe it is the only earth which forms a tranſparent glaſs by combination with alkalis; but the name of ſilex, derived from that of ſiliceous earth, which has been given to it, becauſe it exiſts in all the ſiliceous ſtones, is that to which we give the preference.

The ſecond kind of earth, which we regard as ſimple and pure, is the argillaceous or alumine. In its ſtate of purity, it preſents the following characters. It is almoſt always opaque; or, if it enters into the compoſition of other ſtones, their tranſparency becomes inferior to that of the ſiliceous claſs. It is always diſpoſed in thin plates, or laminæ on each other. This diſpoſition correſponds to the cryſtalline form which the former earthy matter conſtantly aſſumes. Though it has no more taſte than vitrifiable earth, it ſeems nevertheleſs to have a kind of action on our organs, as appears by its adheſion to the tongue. Its force of aggregation is never ſo conſiderable as that of vitrifiable earth; whence it follows, that argillaceous ſtones are never very hard, but break by the blow of a ſteel inſtrument, without ſcratching it, or giving fire, as vitriſiable earths do. This ſmall force of aggregation renders this earth much more diſpoſed to combination, and therefore we meet with pure clay much more ſeldom than pure rock cryſtal or quartz. It may be readily conceived, after this obſervation, why clays are almoſt always coloured, and why there are few clays which poſſeſs the aluminous characters in an eminent degree. Alumine expoſed to the action of heat, experiences an alteration which vitrifiable earths do not. Inſtead of remaining unchanged, it hardens, and obtains an aggregation ſtronger than in its natural ſtate. It even approaches the vitrifiable earth in hardneſs and want of diſpoſition to combine, after ſuch treatment. Water has ſome action on alumine, which it penetrates, and renders ſoft and ductile. That this is a kind of combination, is evinced by the adheſion of theſe two ſubſtances, which is ſuch, that they cannot be ſeparated but by the action of a ſtrong heat continued for a long time. The property of alumine to form a paſte with water, and become hard by fire, is of great value in the arts. Laſtly, The property of entering into combination with a great number of ſubſtances, eſpecially diſtinguiſhes it from the vitriſiable earth. From this it is that alumine is found in a great number of compounds; and from the conſideration of this, we have ſpoken more largely of this earth, as a knowledge of its leading characters is neceſſary, in order to diſtinguiſh it in chemical operations.

Theſe two earths we have thought fit to diſtinguiſh, as they both poſſeſs the characters of elementary ſubſtances, and no chemiſt has yet ſucceeded in decompoſing them. We are not ſufficiently advanced in our knowledge concerning the origin, formation, or even the chemical properties of theſe earths, to pronounce with certain chemiſts, that the one is more ſimple than the other, and that the latter is only a modification of the former. We cannot admit, that the earth of rock cryſtal, or ſilex, is the baſe of alumine, which, as far as is yet known, is not the ſame ſubſtance, either attenuated, divided, or elaborated; for no chemiſt has ever converted the one into the other.

It rarely happens that ſiliceous or aluminous earth is found in nature in a ſtate of purity. The former alone enjoys this privilege in rock cryſtal; doubtleſs becauſe, as we have obſerved, of its great hardneſs and force of aggregation. Even this is often coloured by foreign matters. It is ſtill more frequently altered and combined with colouring matters in quartz. Aluminous earth is yet leſs frequently found pure. The greateſt part of the earths and ſtones, to which naturaliſts have given different names, are compoſed of one or the other, or both theſe earths; or of ſaline ſubſtances, eſpecially lime, and magneſia, with metallic matters, moſt frequently iron. To obtain a conviction of this truth, nothing more is neceſſary than to caſt an eye over M. Monnet's work, in which that chemiſt ranges ſtones after their conſtituent parts; an attempt worthy of great praiſe, but which, while it ſhows the great advantages lithology may expect to receive from chemiſtry, affords at the ſame time a proſpect of the difficulties that ſtill attend the accurate claſſification of ſtones, from their chemical properties. The following chapter will be more particularly employed on this ſubject[a].

NOTE ON CHAPTER VIII.

[a] The number of the primitive earths is ſtill undetermined. Fourcroy reckons only five; but there is good reaſon to believe that number is too ſmall.

Several other ſubſtances have of late years been admitted into the claſs of primitive earths by chemiſts and mineralogiſts of great note; but whether theſe ſubſtances be actually deſerving of that character, time, and a more rigorous examination, alone can determine. We ſhall here mention the principal.

Adamantine ſpar was for ſome time ſuppoſed to contain a peculiar earth; but the accurate analyſis of Mr. Klaproth has ſhown this to be an error. From his analyſis, it appears that 100 parts of the adamantine ſpar brought from China conſiſts of - - - -

	Alumine.	*Oxyd of Iron.*	*Silex.*
	84	7,50	6,5
Adamantine ſpar from Bengal, -	89,50	1,25	15 1-half.

See *Klaproth Beyträge zur Chemiſchen Kenntniſs der Mineralkörper*, B. III. ſ. 47.

Zirconia, or *Jargonia.*—This earth is found in a ſtone brought from the iſland of Ceylon. It has a great reſemblance to clay, though it differs from it in ſome of its properties. Zirconia is ſoluble in ſulphuric, nitric, muriatic, and concentrated acetic acids. It is precipitated from its ſolution in acids by alkalis either in their mild or cauſtic ſtate. When mild alkalis are uſed, the zirconia does not diſcover any affinity for their carbonic acid. It is inſoluble in alkalis; neither does it melt with theſe ſubſtances when expoſed to the greateſt degree of heat. It is infuſible in microcoſmic ſalt; but yields to borax, yet without any efferveſcence. For a more particular account of the properties of this earth, ſee *Kirwan's Mineralogy*, p. 14.; *Klaproth Beyträge*, XII. 203.; *Manuel de Mineralogiſte, par M. Mongez*, Tom. I. 150.; *Journ. de Phyſ.* 179, *pour l'an.* 1790.

Strontites, or *Strontian earth*, is found united to carbonic acid in Gneis in the lead mines of Strontian in Argyleſhire. It exiſts alſo in the proportion of from 1 to 2 per cent. in ſtones of the barytical genus. When pure, it has a pungent, acrid taſte; and is ſoluble in the proportion of 2 7-10th grains to the ounce of water. This ſolution quickly attracts carbonic acid from the atmoſphere, and becomes covered with an inſoluble cruſt. In this ſtate, an ounce of boiling water diſſolves about 218 grains. During cooling, this earth is depoſited in the form of colourleſs tranſparent cryſtals. It is ſparingly ſoluble in alcohol. It unites with ſulphuric, nitric, muriatic, acetic, oxalic, tartaric, fluoric, phoſphoric, ſuccinic, arſenic, boracic, and carbonic acids.

Theſe combinations all poſſeſs the property of giving a red tinge to the flame of combuſtible bodies; the muriat in the moſt remarkable degree. Strontites decompoſes ſulphat of potaſh; it decompoſes the ſulphats, nitrats, and muriats of lime.

Sulphat of ſtrontites is decompoſed by pure barytes. With ſulphur, ſtrontites, like the other alkaline earths, combines to form an hepar. For a further account of this earth, ſee an excellent paper by Dr. Hope, in the 3d volume of the *Edin. Phil. Tranſ.*; *Klaproth Beyträge*, XVIII. 260.; *Kirwan's Mineralogy*, p. 13.; *Schmeiſſer's Mineralogy*; *Monthly Magazine*, p. 633. for Sept. 1796.; *Richter Ueber Die Neuern Gegenſtänds der Chemie, Achtes Stuck.*

Sydneia, or *Sydney earth*, firſt diſcovered by Mr. Wedgwood in a compound mineral ſubſtance brought from Sydney Cove in South Wales, is ſaid to poſſeſs the following properties: It is fuſible in 150° of Wedgwood's thermometer, which no other ſimple earth is. It is ſoluble directly and immediately in no acid but the muriatic, and in this only when the acid is heated and in a concentrated ſtate.

If to a ſolution of muriat of ſydneia an equal quantity of ſulphuric acid be added, heat and effervescence will be produced, and the muriatic acid will be expelled in white fumes.

Pruſſian alkali does not precipitate this earth from its ſolution in the muriatic and ſulphuric acids; but it is readily precipitated by common alkali, or by the ſimple addition of water. See *Phil. Tranſ.* Vol. LXXX. p. 306.; *Kirwan's Mineragy*, p. 15.

PART II.

CONCERNING

THE MINERAL KINGDOM;

OR,

MINERALOGY.

SECTION I.

EARTHS AND STONES.

CHAPTER I.

GENERAL FACTS AND OBSERVATIONS ON MINERALOGY; THE DIVISION OF MINERALS IN GENERAL, AND OF EARTHS AND STONES IN PARTICULAR; THEIR DIFFERENT CHARACTERS.

THE deſign of natural hiſtory conſiſts in the knowledge of the bodies which conſtitute our globe. The whole is full of grandeur and ſublimity; and its parts are immenſe. This ſcience comprehends all terreſtrial phenomena, from the meteoric changes of the atmoſphere, to the mutations to which the interior parts of the globe are ſubject. The ſurface of the earth, its ſeas, lakes, rivers, mountains, valleys, plains, and caverns; the animated and organized beings which dwell therein, and the inanimate matter of which they are compoſed, occupy by turns the attention of the natural hiſtorian. The man of genius is alone capable of viewing the great deſign at once in all its component parts; the ſcrupulous and indefatigable obſerver attaches himſelf to the detail. The ſeparate conſideration of the parts has produced the various branches of this ſtudy. Theſe are inexhauſtible. Laborious men have conſecrated their lives to the obſervations and deſcriptions of the habits and manners of certain inſects, and have left the ſubject ſufficiently replete with matter for the gratification of future inquirers.

The ſtudy of natural hiſtory would, therefore, be diſcouraging, on account of the immenſity of the proſpect, if the difficulties were not removed by arrangements, by which the memory is relieved and aſſiſted. Theſe arrangements are called methods. They conſiſt in ſuch a diſpoſition of natural bodies, as places thoſe neareſt each other which have ſimilar properties; and others remoter, as their properties differ. The claſſification thus made ought to be founded on characters which are conſtant, obvious, and eaſy to be known.

The diviſion of bodies into three grand orders, called kingdoms, namely, the mineral, the vegetable, and the animal kingdoms, is founded on the moſt ſtriking differences of character. Though the two laſt reſemble each other in ſome of their leading properties, yet they are ſufficiently different from each other in their external form and organization, to be conſidered ſeparately.

Minerals form the maſs of the globe, or rather the external cruſt, as far as the labours of men have penetrated. They do not increaſe in volume, but by juxtapoſition of parts, and the force of attraction. They are ſubject to no alteration, but ſuch as ariſes from the chemical action of ſubſtances on each other. They are called inorganized, or inanimate bodies.

Vegetables, on the contrary, grow larger, by an internal force or principle. They have organs which elaborate the juices they attract from the earth and from the air. They are ſubject to the modifications of living ſubſtances. They grow, live, and die. They produce their like by a true generation.

Laſtly, Animals have more complicated organs than vegetables; their changes are more rapid; and they are much more ſubjected to the action of ſurrounding bodies, in proportion to their loco-mobility, and their higher degree of ſenſibility.

That part of natural hiſtory which relates to minerals, is called mineralogy. The early naturaliſts divided minerals into a great number of claſſes. In their methodical enumeration, they admitted earths, ſands, ſoft ſtones, hard ſtones, precious ſtones, figured ſtones, ſalts, ſulphurs, pyrites, minerals, metals, &c. Thoſe who are deſirous of obſerving the ſucceſſive progreſs of mineralogy, from the time of Henckel, one of the firſt who has treated methodically on this ſubject, to that of Daubenton, whoſe claſſification is a maſterpiece of preciſion and exactneſs, may ſee the ſyſtems in ſucceſſive order collected in the Introduction to the *Manuel de Mineralogiſte* of Mongez, publiſhed in 1784, at Paris. The ſucceſſive periods of this ſcience are marked by the labours of Bromel, Cramer, Henckel, Wolterſtdorff, Gellert, Cartheuſer, Juſti, Lehman, Wallerius, Linnæus, Vogel, Scopoli, Romé de Lille, Cronſtedt, Borne, Monnet, Bergman, Werner, Sage, and laſtly, Daubenton, who in the preſent ſtate of the ſcience has left ſcarcely any thing to be deſired.

To obtain a knowledge of the great number of minerals which compoſe the globe, they muſt be arranged in ſeveral claſſes, diſtinguiſhed by very evident characters. We ſhall, therefore, divide them into three ſections. Under the firſt we ſhall range earths and ſtones, which have no taſte, which are inſoluble in water, and do not burn when heated with contact of air; under the ſecond, ſaline matters, having more or leſs taſte, which melt in water, and do not burn; and under the third, combuſtible ſubſtances, in general not ſoluble in water, and exhibiting a flame more or leſs evident when expoſed to the fire with acceſs of air.

Earths and ſtones form the greateſt part of our globe, and are eaſily diſtinguiſhed from ſalts or inflammable bodies, by their inſipidity, ſolubility, and incombuſtibility. Their regular arrangement in beds, or ſucceſſive ſtrata, conſtitutes mountains or hills, and plains. In the former, they are either in ſhapeleſs maſſes, or in ſtrata inclined to the horizon. In the plains they are horizontally diſpoſed, and covered with a bed of mould fit for the vegetation of plants, which is produced by the decompoſition of the organized bodies that are formed and decay on the ſurface of the earth. The ſeveral kinds of earth are frequently diſtributed in a regular cryſtalline form in the clifts or ſubterraneous cavities. Water, which appears to have formed the greateſt part of theſe, divides them, continually attenuates them, tranſporting them from one place to another, and in general producing in them many changes. Their natural hiſtory is divided into geology and lithology; the former treats of earths, the latter of ſtones. But theſe two, as we have before obſerved, ought to be ranged in the ſame claſs; becauſe earths, if we except the ſoil formed by the reſidue of decayed organized matters, are nothing elſe but ſtones, whoſe aggregation is deſtroyed; and ſtones are formed by the union of earths.

The number of different forms of earths and ſtones being very great, and the knowledge of them of great importance to ſcience, as well as to the common applications of them to uſeful purpoſes, naturaliſts have in all ages been induced to endeavour to diſtinguiſh them by ſure and eaſy methods. The ancients had not the idea of claſſing them from their diſtinctive characters, but contented themſelves with deſcribing their general properties, and the hiſtory of the uſes they were applied to, together with their value, or the degree of eſtimation they were then held in. From this it is that the greateſt part of the ſtones deſcribed by Pliny are not to be found or known. Modern naturaliſts, aware of the inconveniences of this method of deſcribing ſtones, have taken another method of diſtinguiſhing them, with the intention that all future ages may underſtand their deſcriptions. It is from the external and ſenſible properties of theſe ſubſtances that they have diſtinguiſhed them into orders, genera, and ſpecies, and have by that means rendered the ſtudy of them more eaſy and advantageous.

The external and ſenſible characters which diſtinguiſh earths and ſtones in the modern lithological methods, conſiſt in their form, their hardneſs, their internal ſtructure, or their appearance when broken, and their colour. Several naturaliſts have added to theſe ſome of their chemical characters, more eſpecially their habitudes in the fire, and with acids. We ſhall here conſider each of theſe properties, that the application of the general principles to the particular hiſtory of each genus of ſtones may be better underſtood.

§ 1. *Concerning the Form or Figure of Stones, conſidered as one of their general Characters.*

By the form of ſtones, is underſtood the reſpective arrangement of their ſurfaces, with relation to each other. The moſt tranſient view of a collection of ſtones in a cabinet of natural hiſtory, ſhows that ſome poſſeſs a regular geometrical figure, while others are altogether without any ſymmetry as to their form; and that this regularity is in ſome caſes found in tranſparent, and in others in opake bodies. Obſervation has demonſtrated, that ſome kinds of ſtones affect a peculiar form in their cryſtals, and that other kinds are never found but in misſhapen fragments. Many naturaliſts are of opinion that all ſtony matters have the property of taking a cryſtallized form, which is more remarkable in ſome than in others; but that all have their peculiar forms, which are ſenſible even in their ſmalleſt parts. This is the opinion of Romé de Lille, who has written a very copious and exact hiſtory of all mineral ſubſtances relative to their ſeveral cryſtallizations *. This philoſopher diſtinguiſhes the form, which ſtones and all other minerals affect, under three denominations, of determinate, indeterminate, and confuſed cryſtallization, and obſerves, that there is no mineral ſubſtance which does not come under one of theſe three claſſes. The truth is, that as many of theſe affect the ſecond and third kind of cryſtallization, which are irregular, and not eaſy to be diſtinguiſhed, we cannot avail ourſelves much of the cryſtalline form of ſtones to give them poſitive and determinate characters from this circumſtance. Many mineralogiſts have, nevertheleſs, eſtabliſhed entire ſyſtems of lithology and mineralogy on the regular external forms of the matter deſcribed. Linnæus is the firſt who adopted this plan, and though he has not entirely accompliſhed the intention meant to be anſwered in his methodical diviſions, he at leaſt directed the attention of obſervers to the forms of cryſtals, and opened the way to all the diſcoveries ſince made reſpecting them.

Such is the preſent ſtate of opinions relative to the influence of cryſtallography on the ſtudy of ſtones and minerals. It is very uſeful to lead us to the hiſtory of the formation of theſe ſubſtances, and may, in ſome caſes, throw great light on inquiries reſpecting their nature. It may even ſerve to diſtinguiſh them from each other; but it is not ſufficient to ſerve as the baſis of an entire ſyſtem of mineralogy, becauſe it is in reality nothing more than one of the ſeveral means, by the union of which ſuch a ſyſtem may be conſtructed. M. Romé de Lille, who has ſo greatly diſtinguiſhed himſelf by his reſearches into the forms proper to all minerals, has not availed himſelf of this alone in his claſſification of bodies, but has only examined and deſcribed thoſe minerals arranged according to their reſpective ſaline, ſtony, or metallic nature, and their mutual combinations.

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* *Cryſtallographie, ou Deſcription des Formes propres à tous les Corps du Règne Minéral, &c.* Paris, 1783. 4 tom. 8vo.

§ 2. *Concerning Hardneſs, conſidered as a Character of Stones.*

The aggregation of the parts which compoſe ſtones is ſo various, that lithologiſts have advantageouſly made uſe of it to diſtinguiſh them from each other. Some have an aggregation ſo ſtrong, and are conſequently ſo hard, that ſteel of the higheſt temper makes no impreſſion on them. Such are the precious ſtones or gems. Others yield with difficulty to the action of inſtruments; ſuch are quartz, flints, agate, hard ſand-ſtone, porphyry, and granite. All theſe ſtones, when ſtruck againſt a piece of ſteel, produce a great number of ſparks; which circumſtance has occaſioned them to be called ſcintillant or ſparkling. Theſe ſparks ariſe from ſmall portions of the ſteel which are ſtruck off by the ſtone, and ſuddenly ſet on fire by the heat occaſioned by the ſtrong percuſſion they undergo. This heat is ſo conſiderable, that the particles are melted; ſo that when collected, on white paper, and obſerved with a good magnifier, they are found to be a kind of ſemi-vitrified calx, ſimilar to that produced at iron forges, and known by the name of *machefer*, or droſs of iron. Stones that give fire having different degrees of conſiſtence, from gems, and rock cryſtal, to the tender ſandſtones, and ſiliceous breccias of modern formation, the quantity of ſparks muſt vary in the ſame proportion.

There is a great number of ſtones, whoſe aggregation is much leſs conſiderable, and which are ſoft enough to be cut and formed by ſteel inſtruments. Theſe do not give fire with ſteel, but break with different degrees of facility when ſtruck with a hard tool. The difference of conſiſtence in ſtones, which do not give fire with the ſteel, is obſervable in their other properties. Some, as for example marble and alabaſter, receive a good and uniform poliſh; others, as for example, moſt of the argillaceous ſtones, are capable of an inferior or falſe poliſh, and have always a dull greaſy appearance. Some judgment may be formed of the degree of hardneſs the kind of poliſhed ſtones are capable of, by the appearance they exhibit when wetted; the moiſture producing the effect of a poliſh while it laſts.

It is to be noted, that many ſtones may afford ſparks with ſteel, though they are not really of the claſs of ſcintillant ſtones. Theſe are produced by their being of a mixed kind, and containing fragments of ſtones ſufficiently hard to produce ſparks. Thus it is that ſeveral kinds of marble, and calcareous breccias give ſparks, when ſtruck with the ſteel, in conſequence of the quartzoſe or flinty particles intermixed with their calcareous paſte.

The denſity of ſtones is neceſſarily as their ſpecific gravity. Some naturaliſts have conſidered this laſt property as very important for the claſſification of ſtony ſubſtances. M. de Buffon is of this opinion. But this character, however important for aſcertaining the natural order and general nature of theſe ſubſtances, requires accurate experiments to be made, and can be uſed only as an auxiliary in the lithologic methods, in which facility and ſimplicity are neceſſary requiſites to guide ſtudents at their entrance into this part of natural hiſtory.

§ 3. *Concerning the Fracture, conſidered as a Character of Stones.*

When a ſtone is broken, the newly ſeparated ſurfaces exhibit a peculiar arrangement of the integrant particles, which is different in different ſpecies. Lithologiſts call this appearance the fracture, and it affords very uſeful characters to diſtinguiſh ſtones from each other. By comparing the circumſtances which relate to the fracture of all the ſtones we are acquainted with, it is eaſy to reduce theſe fractures to ſeveral kinds.

Some, for example, break like glaſs, with a ſmooth poliſhed ſurface, of a regularly curved figure, and this is called the vitreous fracture. It is obſerved in rock-cryſtal, quartz, &c.

Others preſent a ſurface clean and poliſhed, but formed of ſucceſſive undulations, reſembling thoſe obſerved on ſome ſhells. The two pieces applied together, in general fit each other very neatly. This fracture is diſtinguiſhed by the name conchoidal, or ſhell like. The undulations are of various magnitudes and appearance, as wide, narrow, round, oblong, deep, ſuperficial, &c. and may be obſerved in ſeveral kinds of flint, jaſper, agate, or petro-ſilex.

There is another claſs of ſtones, which, when broken, exhibit, at their ſurfaces an aſſemblage of projecting and rounded points, reſembling grains of ſand worn by the waters. This is called the granulated fracture. It may be eaſily obſerved in ſand-ſtone. The magnitude of theſe ſmall parts affords a number of different diſtinctions. It is with relation to this kind of fracture, that we ſometimes apply the figurative expreſſion *dough* or *paſte* to the fractures of ſtones, and ſay, a ſtone has a fine or a coarſe grain.

Laſtly, There is a great number of ſtones, whoſe fracture ſhows them to be compoſed of many equal laminæ placed upon each other. The great part of theſe being called ſpars, the fracture is thence denominated ſparry. Theſe laminæ differ from each other in their extent, magnitude, thickneſs, tranſparency or opacity, horizontal or oblique poſition, with reſpect to the axis and diameter of the cryſtallized ſtone, that being ſuppoſed to be placed vertically, for they anounce a true cryſtallization when they are brilliant, if they have not a *chatoyant* appearance, the fracture they exhibit is termed lamellar. It is the various diſpoſition of theſe in gems, calcareous or ponderous ſpars, cryſtals, &c. which ſometimes cauſes the brilliant or chatoyant * appearance obſerved in talc, and the various kinds of feldt-ſpar, as the cat's eye, the avanturine, the labrador ſtone, &c.

Some authors have made diviſions of ſtones, founded on their general appearance, together with their fracture. Cartheuſer, in 1755, publiſhed a ſyſtem of mineralogy, in which he diſtinguiſhes ſtones into lamellated, fibrous, ſolid, and granulated. But the fracture alone is inſufficient to ſerve as the baſis of a complete lithological method, and requires to be contraſted with the other characters examined in the preſent chapter †.

§ 4. *Concerning Colour, conſidered as a Character of Stones.*

The various colours obſervable in many ſtones, depend on combuſtible or metallic ſubſtances intimately combined with their other parts. In ſome ſpecimens the colour is uniformly ſpread through the maſs, in others it is ſeen only in certain ſpecks or points. In general the colouring part of ſtones is accidental, or not always found in the ſame kind, and varies according to circumſtances. It is indeed true that the colour is ſufficiently conſtant in ſome ſtones, as the gems, the ſchorls and tourmalins, to ſerve as one of the indications of their kind; but as its utility in this reſpect is very confined, it is not much applied or eſteemed by lithological writers.

Among the colours which ſerve to diſtinguiſh the ſorts and varieties of ſtones, we may diſtinguiſh the uniform, or equally diſtributed colour, accompanied with tranſparency or opacity, and ſuch as are unequally diſtributed in irregular ſpots, in veins, in points, and in bands. We muſt likewiſe pay attention to the quantity or number of colours which are ſometimes obſerved, to the number of ſix or ſeven, as in marbles. From the number and diſpoſition of the colours in theſe natural ſubſtances, it is that they have been divided into ſtones, of one, two, three, or four colours, variegated, ſpotted, veined, marbled, clouded, punctuated, or dotted, or bearing marks of vegetation, or other figures, &c.

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* We have no Engliſh word to expreſs this modification of light.

† Vide *L'Introduction à la Sciagraphie de Bergman, par Mongez le jeune*, p. 21.

§ 5. *Concerning the Alteration produced by Fire, conſidered as a Character of Stones.*

Some mineralogiſts, not content with examining ſtones by the exterior and ſenſible qualities, have alſo ſought for means of diſtinguiſhing them by their chemical characters. The action of fire, and the alteration they are reſpectively ſubject to from this agent, has been regarded by many lithologiſts as a good means for obtaining a knowledge of their differences. They have obſerved that ſome, as for example, quartz, loſe their tranſparency and hardneſs, by fire, but are no otherwiſe changed; that others ſuffer no change, as for example, rock cryſtal; that others again melt, and become converted into a glaſs of a different colour, as ſchorls, zeolite, aſbeſtos, amianthus, garnets; and laſtly, that others loſe their conſiſtence, and part of their weight, without melting, and at the ſame time acquire the property of ſolubility in water, as all the calcareous ſtones do. Other experiments, more numerous and accurate, ſhow, that ſome ſtones loſe their colour in the fire, while in others it is rendered deeper by the ſame agent. Theſe are among the general reſults of the labours of Meſſrs. Pott, D'Arcet, and many other chemiſts.

Theſe various alterations are neceſſary to be known, in order to render the hiſtory of ſtones more complete, and to ſhow their reſpective natures. They ſhow in general, that ſuch ſtones as are the leaſt changed by the fire, are the moſt ſimple; but they cannot be of any great utility in lithological methods, becauſe they require the completion of experiments, which cannot be made but in a long time, and with conſiderable ſkill. Whereas the characters beſt calculated for the claſſification of ſtones, ought to be eaſy to be known or obtained, and either founded on ſuch properties as the eye can aſcertain, or at leaſt may be collected from ſimple and ready trials or eſſays.

It is true indeed, when exterior properties are inſufficient, that we may ſometimes avail ourſelves of the change produced in ſtones by fire, by the help of the blow-pipe recommended by Bergman; but however ſimple this ingenious method may be, it always implies the neceſſity of carrying an apparatus inconvenient to travellers, and the proceſs is better calculated to be performed in a laboratory, than on a lithologic excurſion *.

§ 6. *Concerning the Action of Acids conſidered as a Character of Stones.*

Acids are the ſolvents moſt commonly employed. Though we have not yet ſpoken of theſe ſalts, it is neceſſary we ſhould in this place make a few remarks on the phenomena exhibited by ſome ſtones, when placed in contact with acids. The greater number are not at all acted on, or changed by acids; but there are ſome, which, upon a drop of nitric acid being put on their ſurface, by means of a ſmall tube, are acted on in ſuch a manner, that the eſcape of bubbles, paſſing through the acid, occaſions an appearance reſembling ebullition. This phenomenon is called effervefcence, and is owing to an aeriform fluid ſeparated from the ſubſtance by the action of the acid. This elaſtic fluid is itſelf a peculiar acid, diſengaged by the acid dropped on the ſtone, and is the product of a true decompoſition. All calcareous ſtones containing fixed air, effervefce by the contact of acids, and eſpecially with that of nitre, which is uſually employed in theſe eſſays. This diſengagement of an aeriform fluid, ſhows in reality, that the matter it eſcapes from is a ſaline combination; but as it is a combination poſſeſſed neither of taſte nor ſolubility in water, in any obvious degree, and as it beſides forms a great part of the external cruſt of the globe, naturaliſts have always regarded it as a ſtony ſubſtance.

All ſtones may therefore be diſtinguiſhed into effervefcent and non-efferveſcent. A ſmall phial of nitric acid becomes, therefore, of courſe, a neceſſary article in ſuch excurſions as are made with the intention of examining and collecting ſtones, and together with the magnifier and the ſteel, is the only inſtrument neceſſary to be uſed by the lithologiſt.

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* See Bergman on the Blow-Pipe, at the end of his Chemical Eſſays, tranſlated into Engliſh, and publiſhed in London, 1784.

If a blow-pipe, a piece of charcoal, a ſmall ſilver ſpoon, and three ſmall phials, containing ſalt of ſoda, microcoſmic ſalt, and borax, compoſe an apparatus inconvenient to travellers, and if a proceſs, eaſy to be executed in any place where a candle can be defended from the wind, require a chemical laboratory, the author is right in diſcouraging this excellent ſmall analyſis. Very complete apparatus for this purpoſe are ſold in London, contained in a box no larger than a book in twelves, at Brown's bookſeller, the corner of Eſſex-ſtreet, near the Strand. T.

Since Bergman has recommended the examination of ſtones by fire, with the aſſiſtance of the blow-pipe, they are eſſayed likewiſe with ſoda, borax, and fuſible ſalt of urine, which act differently on theſe matters according to their nature; and in general exhibit a fuſion more or leſs complete, accompanied with different phenomena. We ſhall ſpeak more largely on this method of analyzing ſtones, in the chapter wherein the other methods of analyzing them will be treated of.

CHAPTER II.

THE LITHOLOGIC METHOD OF M. DAUBENTON.

Extracted from his Tableau de Mineralogie.

AMONG all the lithologiſts who have attempted the methodical diſtribution of ſtones, there is no one who has given diviſions more exact, more clear, or more eaſy to be underſtood, than M. Daubenton. The ſkill with which this celebrated naturaliſt has contraſted the characters of theſe ſubſtances, renders his method much more accurate and uſeful, than all thoſe hitherto propoſed. The properties he has ſelected as the baſes of his characters, are all conſtant and eaſy to be known. They conſiſt eſpecially in the regularity or irregularity of form; tranſparency more or leſs perfect, or opacity; conſiſtence, or hardneſs; poliſh, which ſtones are ſuſceptible of; form, or reſpective arrangement of integrant parts, which occaſions the vitreous, conchoidal, granulated, lamellated, and ſpathoſe fractures; the colours, when they are not accidental; the ſurface dull, brilliant, or chatoyant. As it would be impoſſible to improve on the preciſion and perſpicuity of the ſyſtem of M. Daubenton, we ſhall exhibit in this place his diviſions of earths and ſtones, as he has laid them before the public in his *Tableau Mèthodique des Mineraux**.

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* *Tableau Mèthodique des Minéraux, ſuivant leurs différents Natures, et avec des Charactères diſtinctifs, appareus, ou faciles à reconnoitre.* Par M. Daubenton, &c. Paris, chez Demonville, Pierres, Debure, Didot l'aîné, &c. 1784, in-8. de 36 pages.

ORDER I.

MINERALS.

SANDS, EARTHS, AND STONES *.

Theſe Subſtances do not diſſolve in Water like Salts, nor burn like combuſtible Bodies, nor have the Brilliancy of Metallic Matters.

CLASS I.

Stones that give Fire with Steel.

GENUS I. Quartz.

Cryſtalline Subſtance, fracture vitreous, not lamellated.

Species I. Opake, or ſemi-tranſparent Quartz.

Varieties.
1. fat.
2. grained.
3. milky.
4. foliated.
5. cryſtallized.

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* In this place, we only give a part of the table of M. Daubenton; but when we treat of the hiſtory of ſalts and combuſtible bodies, we ſhall give the diviſions of this philoſopher, relating to theſe ſubſtances. As we have been careful to give an exact copy of his table, even ſo far as to uſe the ſame type or characters, we think it proper to ſubjoin the beginning of the advertiſement of M. Daubenton, relating to the methodical diviſion of ſtones. The following are the words of this celebrated naturaliſt:

"This table has been expoſed in manuſcript ſince the year 1779, in the Hall of the College Royal, during my lectures; and many copies of it have been taken. I have made various alterations, as I have received or acquired new information reſpecting mineralogy. I have even abandoned, for the preſent, my deſign of inſerting the chemical analyſis of different minerals in my tables, as I had begun to do, becauſe a ſufficient number has not yet been analyzed. My principle object in drawing out this preſent table, has been to facilitate the ſtudy of mineralogy. The beſt means of diffuſing the knowledge of the ſciences, is to ſimplify their elements. Methodical diviſions promote this intention; for though it is impoſſible to give deſcriptive characters perfectly agreeing with nature, yet, ſuch as they are, they are convenient, uſeful, and even neceſſary. In the full explanation of my table, which I propoſe to give in my *Leçons d'Hiſtoire Naturelle*, now in the preſs, I ſhall ſhow the advantages and defects of my methodical diſtribution of minerals. I ſhall only take notice in this place, that minerals are diſtributed in this table into orders, claſſes, ſpecies, and varieties. The diſtinctive characters of each article of theſe methodical diviſions are printed in Italics.

Species II. Tranſparent Quartz, ROCK CRYSTAL.

Two Pyramids of ſix Faces, with or without a Priſm of ſix Sides (between them).

Varieties.
1. cryſtallized.
2. rough.
3. white.
4. red. *BOHEMIAN RUBY.*
5. yellow. *OCCIDENTAL TOPAZ.*
6. ruddy or blackiſh. *SMOKY TOPAZ.*
7. green.
8. blue. *WATER SAPPHIRE.*
9. violet. AMETHYST.
10. irideſcent.

Species III. Quartz in agglutinated fragments, Grit-ſtone, or Siliceous Grit,

Granulated fracture.

Varieties.
1. hard Grit-ſtone.
2. friable.
3. from the Levant. *Very fine grain.*
4. Filtering Stone. *Porous.*
5. glittering.
6. veined.
7. exhibiting figures of plants.
8. coarſe grained.

Species IV. Quartz in looſe Grains, SAND,

Vitreous ſurface.

Varieties.
1. angular.
2. rounded.
3. moving.
4. fluid.

Species V. Quartz in concrete Maſſes.

Sandy and quartzoſe Pudding Stones, or breccias.

GENUS II. Semi-tranſparent Stones,

Vitreous fracture, ſometimes conchoidal,

Species I. Agates,

Of all colours, except the milk-white, the fine red, the orange, and the green.

Varieties.
1. clouded.
2. punctuated.
3. ſpotted.

" Among the names, there are ſome in Roman capitals, and others in Italic capitals. The former are ſuch as I think moſt ſuitable to the things they denote; the others are ſynonymes, whoſe uſe would be attended with inconvenience, and are inſerted only to facilitate the knowledge of the things deſcribed."

Varieties.
4. veined.
5. onyx.
6. iriſed.
7. preſenting the appearance of herbs.
8. preſenting the appearance of moſs.

Species II. Chalcedonies,

Milky tranſparency.

Varieties.
1. reddiſh.
2. blueiſh.
3. veined.
4. onyx.
5. irideſcent. OPALS.
6. rounded and ſolid. GIRASOLS.
7. rounded and hollow. HYDROPAL CHALCEDONY (Enhydre).
8. in ſtalactites.
9. in ſediment.
10. hydrophanes.

Species III. Carnelians,

Beautiful red.

Varieties.
1. pale.
2. punctuated.
3. onyx.
4. exhibiting figures of herbs.
5. in ſtalactites.

Species IV. Sardonyx,

Orange colour.

Varieties.
1. pale.
2. veined.
3. onyx.
4. preſenting figures of herbs.
5. blackiſh.

Species V. Flints,

Grey, white, reddiſh, blackiſh.

Varieties.
1. with tubercles.
2. in layers.

Species VI. The Praſeum,

Green.

Varieties.
1. green.
2. clouded.
3. ſpotted.

Species VII. Jade,

Greaſy poliſh.

Varieties.
1. whitiſh.
2. olive colour.
3. green.

Species VIII. Petroſilex,

Tranſparency of wax, conchoidal fracture.

Varieties.
1. white.
2. reddiſh.
3. veined.

GENUS III. Opake Stones,

Vitreous fracture, ſometimes conchoidal, or dull.

Species I. Mill Stone,

More or leſs porous.

Varieties.
1. porous.
2. denſe or full.

Species II. Pebbles,

Concentric layers.

Varieties.
1. ſpotted.
2. veined.
3. onyx.
4. oculiform.
5. preſenting the figure of herbs.
6. concreted into breccias. PUDDING STONES.

Species III. Jaſper,

Vitreous fracture, often dull, and without concentric layers.

Varieties.
1. green.
2. red.
3. yellow.
4. brown.
5. violet.
6. black.
7. grey.
8. white.
9. clouded.
10. ſpotted.
11. veined.
12. onyx.
13. flowered.
14. univerſal.
15. fragments united in breccias.

GENUS IV. Scintillating Spar. FELD-SPATH.

Species I. Feld-Spath, regularly cryſtallized,

Varieties.
1. in oblique (angled) priſms of four ſides.
2. in ſix-ſided priſms, with ſummits of two planes.
3. in ten-ſided priſms, with ſummits of two planes and four facets.

Species II. Feld-Spath, cryſtallized confuſedly.

Varieties.
1. white.
2. pearl grey. FISHES EYE.

Varieties.
- 3. red.
- 4. red, with brilliant ſpangles. NATURAL AVANTURINE.
- 5. green.
- 6. blue.
- 7. violet.
- 8. green and blue, by internal reflection. *LABRADOR STONE.*
- 9. variouſly coloured, by internal reflection. CAT'S EYE.

GENUS V. Cryſtal Gems,

Tranſparent and lamellated, not electrifiable by heat alone without friction.

Species I. Red,

Varieties.
- 1. Garnets,
  cryſtallized with 12, 24, or 36 facets. There are alſo yellow, brown, &c. garnets.
- 2. The balaſs Ruby,
  roſe-colour, octahedral cryſtals.

Species II. Red and orange.

Varieties.
- 3. Spinell Ruby,
  fire colour, cryſtallized like the balaſs ruby.
- 4. Vermilion,
  cryſtallized like the garnet.
- 5. Hyacinthe-la-belle,
  cryſtallized under 4 hexagonal ſides with ſummits having 4 rhomboidal facets.

Species III. Orange-coloured.

Variety. 6. Hyacinths,
cryſtallized like the hyacinthe-la-belle.

Species IV. Yellow.

Varieties.
- 7. Oriental Topaz,
  cryſtallized in 2 pyramids of 6 facets.
- 8. Saxon Topaz,
  cryſtallized in priſms of eight ſides, with ſummits of 13 facets.

Species V. Yellow and green.

Variety. 9. Peridots, *CHRYSOLITES,*
cryſtallized in a priſm of 16 ſides, with pyramids of 6 facets.

Species VI. Green.

Variety. 10. Emeralds of Peru,
cryſtallized in ſix-ſided priſms.

Species VII. Green and blue.

Variety. 11. Aqua-marine,
cryſtallized like the Saxon topaz.

Species VIII. Blue.

Variety. 12. Oriental Sapphire,
cryſtallized like the oriental topaz.

Species IX. Indigo.

Variety. 13. Indigo Sapphire,
cryſtallized like the oriental topaz and ſapphire.

Species X. Red and violet *.

Varieties.
- 14. Syrian Garnets,
  cryſtallized like the garnet.
- 15. Oriental Ruby,
  cryſtallized like the topaz and oriental ſapphire.

GENUS VI. Cryſtal Gems, Tourmalins,

Compoſed of laminæ perpendicular to the axis of the cryſtal, electric by heat alone without friction.

Varieties.
- 1. Braſilian Ruby,
  red in a priſm of four ſides, with pyramids of four facets.
- 2. Braſilian Topaz,
  yellow, cryſtallized like the Braſilian ruby.

GENUS VII. Tourmalins,

Electric by heat alone without friction, and without laminæ perpendicular to the axis of the cryſtal.

Varieties.
- 1. Tourmalins of Ceylon,
  tranſparent, orange-coloured, not much furrowed on the ſurface.
- 2. Tourmalins of Spain,
  tranſparent in a ſtrong light, orange-coloured, very much furrowed.
- 3. Tourmalins of Tyrol,
  tranſverſal fiſſures in the priſm.
- 4. Tourmalins of Madagaſcar,
  SHORLS OF MADAGASCAR, opake, black.
- 5. Lenticular Tourmalins.
- 6. Peridots of Ceylon,
  yellow and green, much furrowed.
- 7. Peridots of Brazil,
  yellow and green, much furrowed.
- 8. Emeralds of Brazil,
  green.
- 9. Sapphire of Brazil,
  blue †.

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* Such gems as are formed without colouring matter are white. Note of M. Daubenton.

† All theſe tourmalins, except the lenticular, are cryſtallized in nine-ſided priſms, with ſummits of three or ſix facets. Note of M. Daubenton.

GENUS VIII. Schorls,

Not electric by heat without friction, opake cryſtals, or long green ſemi-tranſparent needles.

Species I. Cryſtallized Shorls.

Varieties.
1. oblique (angled) priſm of four ſides.
2. ſix-ſided priſm. PIERRE DE CROIX.
3. ſix-ſided priſm, with ſummits of two facets, or pyramids of three or four facets.
4. eight-ſided priſm, with ſummits of two facets.

Species II. In articulated fragments.

Varieties.
1. Spathoſe Schorl. Striæ with ſpathoſe facets.
2. in maſſes. SCHORL PASTE (Paſte de Shorl) brilliant points in the fracture.

GENUS IX. Azure Stone,

Opake and blue.

Varieties.
1. purpliſh blue.
2. blue.

CLASS II.

Earths and Stones, which do not give Fire with Steel, and do not effervеſce with Acids.

GENUS I. Clays,

When moiſt they are ductile; when dry they take a poliſh, by being ſlightly rubbed with the hand.

Species I. Clays abſolutely infuſible.

Varieties.
1. uſed to make pots for the glaſs-houſe.
2. for tobacco pipes.

Species II. Clays partly fuſible.

Varieties.
1. for porcelain.
2. for Engliſh pottery.
3. for ſtone-ware.

Species III. Clays entirely fuſible.

Varieties.
1. for common pottery.
2. for delf-ware.
3. for chimney tiles (Dutch tiles).
4. for tiles.
5. for bricks.

GENUS II. Shiſtus,

Argillaceous and foliated fracture.

Varieties.
1. black ſtone.
2. common ſhiſtus or ſlate.
3. writing ſlate.
4. poliſhing ſtones.
5. green ſtone.
6. Hone (Pierre à raſoir).
7. fragments united in breccias.

GENUS III. Talc,

Poliſhed glittering plates, without Spathoſe fracture.

Species I. Talc in large leaves or plates.

Variety. Muſcovy talc.

Species II. In ſmall leaves.

Variety. Mica.

GENUS IV. Steatites,

Greaſy feel, like tallow.

Species I. Steatites in laminæ.

Varieties.
1. fine French chalk (de Briançon).
2. coarſe French chalk (de Briançon).

Species II. Compact Steatites.

Varieties.
1. Soap Rock (Pierre de lard).
2. Spaniſh chalk.

Species III. Lapis ollaris.

Varieties.
1. Como ſtone.
2. foliated Lapis ollaris.

GENUS V. Serpentines,

The poliſh and colours of marble.

Species I. Opake Serpentines.

Varieties.
1. ſpotted.
2. veined.

Species II. Semi-tranſparent Serpentines.

Varieties.
1. granulated.
2. fibrous.

GENUS VI. Amianthus,

Filaments not calcinable, flakes or leaves lighter than water.

Species I. Amianthus with ſoft (or flexible) fibres.

Varieties.
1. Amianthus with long fibres.
2. with ſhort fibres.

Species II. Amianthus with hard (or brittle) fibres.

Varieties.
1. Aſbeſtos, eaſily ſeparable into parts (mur)
2. Aſbeſtos, difficultly ſeparable (non mur).

Species III. Amianthus in flakes or leaves.

Varieties.
1. foſſil leather.
2. foſſil cork.

GENUS VII. Zeolite,

Cryſtallized in divergent radii, or convertible into a jelly by ſolution in acids.

Species I. Cryſtallized Zeolite.

Species II. Compact Zeolite.

Varieties.
1. white.
2. blue.
3. red.

GENUS VIII. Fluor Spar.

Fragments with triangular faces, all inclined to each other.

Species I. Fluor Spar in Cryſtals.

Varieties.
1. octahedrons.
2. cuneiform octahedrons.
3. with 14 facets.
4. cubic.

Species II. Fluor Spar in irregular Maſſes.

GENUS IX. Ponderous Spar,

Rhomboidal fragments, the lateral faces perpendicular to the baſes.

Species I. Cryſtallized Ponderous Spar.

Varieties.
1. in rhomboidal plates.
2. in octahedrons with acute ſummits.
3. in octahedrons with obtuſe ſummits.
4. in hexagonal plates with acute ſummits.
5. in hexagonal plates with obtuſe ſummits.
6. in tables.
7. in cock's combs (or lenticular).

Species II. Ponderous Spar cryſtallized confuſedly.

BOLOGNA STONE.

GENUS X. Heavy Stone. *TUNGSTEN,*

Reſembling Fluor Spar in the form of its fragments, but much heavier; it becomes yellow in acids.

CLASS III.

Earths and Stones which efferveſce with Acids *.

GENUS I. Calcareous Earths.

Efferveſcence with Acids.

Species I. Compact.

Variety. Chalk.

Species II. Spongy.

Variety. Stone-marrow.

Species III. In powder.

Variety. Foſſil Flour.

Species IV. Conſiſtence of cream.

Variety. Lac lunæ.

Species V. Figured.

Variety. Congealed.

GENUS II. Calcareous Stones.

Colours and poliſh are bad.

Species I. Coarſe grained.

EXAMPLE.

Limeſtone from Arcueil.

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* Though theſe ſubſtances are at preſent regarded by chemiſts as neutral ſalts, formed by the union of lime and carbonic acid, we think it proper to exhibit them in this place, at the end of earthy ſubſtances, in order to give a connected view of the method of M. Daubenton. Naturaliſts, who avail themſelves of external and ſtriking characters in their diſtribution of ſubſtances, act properly in ranking them among earths. They will be conſidered under another point of view in the hiſtory of ſaline matters. Note of Mr. Fourcroy.

Species II. Fine grained.

EXAMPLE.

The Thunderſtone.

GENUS III. Marbles,

Granulated fracture, fine colours, good poliſh.

Species I. Marbles of ſix colours.

Varieties.
White, grey, green, yellow, red, and black.
EXAMPLE.
Marble from Wirtemberg.

Species II. Marbles of two colours.

Varieties.
15 in number, formed by the combinations of 6 colours, 2 together.
EXAMPLE.
white and grey.
Marble of Carrara.

Species III. Marbles of three colours.

Varieties.
20 in number, formed by the combination of 6 colours, 3 together.
EXAMPLE.
grey, yellow, and black.
Lumachello.

Species IV. Marbles of four colours.

Varieties.
15 in number, formed by the combination of 6 colours, 4 together.
EXAMPLE.
white, grey, yellow, and red.
Brocatello from Spain.

Species V. Marbles of five colours.

Varieties.
6 in number, formed by the combinations of 6 colours, 5 together.
EXAMPLE.
white, grey, yellow, red and black.
Breccias of old Caſtile.

GENUS IV. Calcareous Spar.

Regular form, ſpathoſe fracture.

Species I. Cryſtallized calcareous ſpar.

Varieties.
1. obtuſe rhomboidal figure,
Iceland Spar.
2. lenticular rhomboidal figure.
3. lenticular rhomboidal figure, with 6 triangular faces.
4. acute rhomboidal figure.

Varieties.
- 5. with 12 pentagonal faces.
- 6. with 3 triangular faces.
- 7. ſix-ſided priſm.
- 8. ſix rhombic ſides, with 6 faces lozenge-wiſe.
- 9. with 12 ſcalene triangular faces.
- 10. with 12 faces of 4 or 5 ſides, and 6 quadrilateral facets.
- 11. with 6 hexagonal faces, and 12 quadrilateral facets.

Species II. Striated calcareous ſpar.

Varieties.
- 1. in parallel ſtriæ.
- 2. in divergent ſtriæ.

Genus V. Concretions.

Succeſſive coats.

Species I. Stalactitical Concretions.

Varieties.
- 1. in columns.
- 2. tabular.
- 3. reſembling alabaſter.

Species II. Concretions by incruſtation.

Species III. Concretions by ſediment.

Varieties.
- 1. by horizontal ſediments.
- 2. by rounded ſediments.

CLASS IV.

Mixed Earths and Stones.

Mixed earths.

Genus I. Sand and clay.

Species. Sand for founders.

Variety. Sand from Fontenai-aux-roſes.

Genus II. Sand and calcareous earth.

Genus III. Clay and calcareous earth.

Species. Marle.

Varieties.
- 1. marle, armenian bole.
- 2. marle, ſealed earth.
- 3. ſtone for taking ſpots out of cloth. (pierre à detacher)
- 4. fuller's earth.
- 5. porcelain earth.
- 6. pipe clay.
- 7. potter's clay. (terre à fayance)
- 8. white marle.
- 9. marle in flakes.
- 10. marle for manure.

Mixed ſtones.

OF TWO GENERA.

Quartz and ſcintillating ſpar,	Granitin.
Quartz and ſchorl,	Granitello.
Quartz and ſteatites,	Quartzoſe ſteatites.
Quartz and mica,	Micaceous quartz.
Tranſparent quartz and mica,	Micaceous cryſtal.
Quartz in grit and gem ſtone,	1. Garnet on grit ſtone. 2. Garnet in grit ſtone.
Quartz in grit and mica,	Micaceous grit.
Quartz in grit and calcareous matter,	1. Cryſtallized grit. 2. Grit in ſtalactites.
Quartz in ſand and opake ſtone,	Sandy and ſiliceous breccias.
Quartz in ſand and ſchiſtus,	Scintillating ſchiſtus *horn-ſtone. trap.*
Quartz in ſand and zeolite,	Scintillating zeolite.
Scintillating ſpar and paſte, or cement of ſchorl,	Ophites.
Semi-tranſparent ſtone, with opake ſtone,	Jaſperated agate, or agatized jaſper.
Schorl and mica,	Micaceous ſpathoſe ſchorl.
Schiſtus and mica,	Micaceous ſchiſtus.
Schiſtus and marble,	Florence marble.
Serpentine and marble,	1. green Egyptian marble. 2. ſea green marble. 3. green antique marble. 4. green marble of Suza. 5. green marble of Varalta.
Ponderous ſpar and calcareous matter,	Alkaline ponderous ſpar.

OF THREE GENERA.

Quartz in ſand, ſchiſtus and mica,	Rough wheat-ſtone.
Quartz, gem, and mica,	Garnet rock.
Quartzoſe paſte, ſcintillating ſpar in large fragments and ſchorl,	Porphyry.
Quartzoſe paſte, ſcintillating ſpar in large fragments and ſchorl,	Serpentine. *hard ſerpentine.*
Quartz, ſchorl and ſteatites,	Tuberculous rock.
Quartz, ſcintillating ſpar, and ſchorl,	Granite.

OF FOUR GENERA.

Quartz, ſcintillating ſpar, ſchorl, and mica,	Granite.
OF SEVERAL GENERA MORE OR LESS IN NUMBER, UNITED IN BRECCIAS,	Univerſal breccias.

DOUBLE BRECCIAS.

Varieties.
1. Fragments of porphyry, with a paſte of porphyry.
2. Fragments of granite, with a paſte of ſchorl.

VOLCANIC PRODUCTS *.

Genus I. Lavas, or volcanic Matters; that is to ſay, formed by Volcanos.

Species I. Porous Scoriæ.

Varieties.
1. in irregular maſſes.
2. in ſtriped maſſes.
3. in ſtalactical forms.
4. in fragments. LAPILLO.
5. in ſmall fragments. POUZZOLANA.
6. in powder. VOLCANIC CINDERS.

Species II. Baſaltes.

Compact and ſcintillating, blackiſh cinereous fracture, with brilliant points, without ſmall plates, like thoſe of ſcintillating ſchiſtus.

Varieties.
1. in irregular maſſes.
2. in round maſſes.
3. in flat maſſes or tables.
4. in priſms of 3, 4, 5, 6, 7, 8, or 9 ſides.
5. in articulated priſms.

Species III. Glaſs.

Varieties.
1. in detached fibres. GLASS GALL.
2. in agglutinated fibres. PUMICE STONE.
3. in compact maſſes. VOLCANIC SCORIA. *LAPIS OBSIDIANUS.*

Genus II. Volcanified Matters or Subſtances altered by the heat of volcanos appearing to have been *baked, calcined, melted,* or *vitrified.*

Species I. Granite.
II. Garnet.
III. Hyacinth.
IV. Mica.
V. Peridot.
VI. Quartz.
VII. Schorl.
VIII. Scintillating Spar.
IX. Calcareous Matters.
X. Baked Earths, Tripoli.

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* M. Daubenton places the volcanic products at the end of the minerals, without ranging them under any one of the four orders that conſtitute his method. As it is uſual to ſtudy the hiſtory of thoſe ſubſtances together with ſtones, I have thought proper to adjoin them here. F.

STONES, whoſe nature is not ſufficiently known to indicate the claſſes to which they belong.

Jargon of Ceylon,

Cryſtallized in rectangular priſms, with pyramids of 4 triangular faces.

It ſeems that the name of Jargon is given to many ſtones, whoſe ſtructure is yet unknown.

Macles,

In ſquare priſms or cylinders, whoſe tranſverſe ſection preſents a blue croſs.

The Macle has been regarded as a ſchorl; but this opinion is not yet proved.

White Cryſtals,

In flattened priſms of 10 ſides, with 2 ſummits of 4 faces, one forming a concave, and the other a convex ſolid angle.

Violet or green Cryſtals,

Rhomboidal with 2 facets inſtead of two oppoſite angles.

The name of Schorl has been given to theſe white, violet, and green cryſtals, though they do not appear to be of the nature of ſchorls.

CHAPTER III.

ON CLASSIFICATION OF EARTHS AND STONES, ACCORDING TO THEIR CHEMICAL PROPERTIES.

Chemists, who have employed themſelves in the examination of minerals, have adopted the opinion, that it is of importance to aſcertain their mutual agreement or difference from their reſpective nature and chemical properties. And though their labours have not yet been ſufficiently diverſified and extended with reſpect to earths and ſtones, to afford a foundation for any very accurate arrangement of theſe ſubſtances on ſuch principles; it is, neverthelefs, of importance to know the actual ſtate of the information we poſſeſs concerning their chemical properties, and the influence thoſe properties may have on the method of claſſing them.

Among the many philoſophers who, ſince the time of Cronſtedt, have availed themſelves of the chemical properties in the claſſification of earths and ſtones, Meſſrs. Bucquet, Bergman, and Kirwan, have ſucceeded the beſt, and have exhibited the moſt valuable and complete ſyſtems of lithology, conſidered chemically. The order followed by theſe three chemiſts not being the ſame, and each poſſeſſing its own peculiar advantages, we think proper to explain them in order, at the ſame time pointing out their reſpective defects.

§ 1. *The Chemical Diviſion of Earths and Stones, propoſed by M. Bucquet.*

Mr. Bucquet, after having long endeavoured to unite the diſtinctive external characters made uſe of by naturaliſts in their arrangement of earths and ſtones, with thoſe which chemiſtry affords, had at length adopted a compound arrangement, which he propoſed to have uſed in his lectures, when his death deprived the ſcientific world of the continuance of his labours. In the converſations I had the happineſs to enjoy with him during the lingering illneſs to which he at laſt fell a ſacrifice, I collected every detail relative to his lithologic method; and the fruit of theſe valuable converſations have been already communicated to the public in the firſt edition of this work. I ſhall here repeat the ſame, with the addition of ſuch notes as the labours of men of ſcience ſince the year 1779 have rendered neceſſary.

According to Mr. Bucquet, earths and ſtones are divided into three ſections. The firſt comprehends the ſimple earths and ſtones; the ſecond, the compounds of thoſe ſimple bodies; and the third, the mixtures of either or both.

Simple earths and ſtones in a ſtate of purity are inſipid, dry, hard, inſoluble, and infuſible ſubſtances. If ſome of theſe appear to poſſeſs theſe characters in an inferior degree, more particularly by being in a certain manner fuſible, it is always to be attributed to the admixture of foreign matters. The chemical analyſis ſhows their purity, by its inſufficiency to ſeparate them into other more ſimple ſubſtances. The number of theſe ſtones is much leſs than Bucquet ſuppoſed.

Compound earths and ſtones muſt be conſidered as combinations of different ſimple earths, with ſaline and metallic ſubſtances. Theſe combinations have been made in the great laboratory of nature, by means of water or of fire. Their chemical characters are fuſibility, the property of affording various kinds of glaſs by the action of fire, and the property of being ſeparated into other more ſimple ſubſtances by the action of ſolvents, more eſpecially acids.

Mixed earths and ſtones are known to be ſuch by the eye. They ſeem to be compoſed of an irregular aſſemblage of different ſtones or earths, either ſimple or compound. It may readily be conceived that this irregular mixture muſt be mechanically ſeparated into its parts before the chemical analyſis can be proceeded on, which muſt be done by the examination of each kind by itſelf. Chemical experiments may then determine their nature with certainty.

SECTION I.

Simple Earths and Stones are divided into four Orders.

ORDER I. VITREOUS STONES.

They poſſeſs extreme hardneſs and perfect tranſparency; their fracture is vitreous; they give fire with the ſteel; and the action of heat alters neither their tranſparency nor their hardneſs.

This firſt order contains two genera; rock cryſtal, and the vitreous precious ſtones.

GENUS I. Rock Cryſtal.

Rock cryſtal exhibits all the characters of vitreous precious ſtones, in the moſt eminent degree. It is diſtinguiſhed from the following genus by its fracture, which is ſimilar to that of glaſs. Its various kinds may be diſtinguiſhed—

1. *With reſpect to their form.*

Species.—1. Solitary hexahedral cryſtals, with two hexahedral pyramids. According to the Abbé Rochon, they produce the diviſion of light uſually called double refraction.

2. Hexahedral cryſtals in groups, with one or two points.
3. Tetrahedral, dodecahedral, flattened, &c. cryſtals. Theſe are always hexahedral cryſtals, whoſe facets are varied and irregular.
4. Rock cryſtal in maſſes from Madagaſcar. It has the property of double refraction, like the firſt.

2. *With reſpect to colour.*

5. Reddiſh rock cryſtal.
6. Smoky cryſtals.
7. Black cryſtals.
8. Yellow cryſtals.
9. Blue cryſtals.
10. Green cryſtals.

3. *With reſpect to accidental events.*

11. Hollow rock cryſtal.
12. Containing water.
13. One cryſtal included within another (emboités).
14. Rounded; pebbles from the Rhine.
15. Encruſted with metallic calces.
16. In gæodes.
17. Containing amianthus.
18. Containing ſchorl.
19. Encruſted with pyrites.

Their formation by water is proved

1. By their tranſparency.
2. By the form of ſmall cryſtals.
3. By the encloſure of one cryſtal in another.
4. By their including ſubſtances alterable by fire.

Theſe ſubſtances are cut and poliſhed into the form of vaſes and into toys.

GENUS II. Vitreous precious Stones.

The precious ſtones placed under this diviſion have all the characters of rock cryſtal, and more particularly its unchangeableneſs by fire. Though this arrangement may ſeem an inverſion of the natural order, and Bergman has aſſured us, that he has found theſe ſtones to conſiſt of ſeveral matters combined together; yet in their hardneſs, tranſparency, and habitudes in the fire, they greatly reſemble rock cryſtal. They differ from it, however, in their ſuperior hardneſs, more lively and clear colour, and in their fracture, which is lamellated. The chemical difference which exiſts between all precious ſtones, more eſpecially as far as relates to the alterations produced in them by fire, induced M. Bucquet to ſeparate them from each other, and to include them reſpectively in ſuch orders of ſtones as they appeared to reſemble the moſt.

The following four precious ſtones are diſtinguiſhed from the reſt, by the appellation vitreous.

Species.—1. Oriental topaz.
2. Hyacinth.
3. Oriental ſapphire.
4. Amethyſt.

M. Daubenton always regarded this laſt as a quartzoſe cryſtal.

ORDER II. QUARTZOSE STONES.

They have leſs hardneſs and tranſparency than the foregoing. Their fracture is vitreous, and they ſtrike fire with ſteel. Heat cauſes them to loſe their hardneſs and tranſparency, and reduces them to a white and opake * earth. We ſhall range four genera of ſtones under this order.

GENUS I. Quartz.

Has all the preceding characters.

Species.—1. Tranſparent quartz, cryſtallized in hexagonal pyramids, without priſms of any ſenſible length, or with very ſhort priſms.
2. Tranſparent quartz in maſſes.
3. Opake, or milky quartz.
4. Fat quartz.

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* It is on account of their different habitudes in the fire, that M. Bucquet thought it proper to diſtinguiſh quartz from rock cryſtal, and to make a particular genus of each. He has alſo obſerved, that this ſtone quenched in water, after having been heated red for ſeveral ſucceſſive times, communicated acid properties to the fluid. Future experiments muſt determine whether this diſtinction be well founded. F.

5. Weathered or rotten quartz.
6. Green, blue, or violet quartz; priſm of amethyſt.
7. Yellow quartz of a lamellated fracture.

Topaz, { Saxon.
Brazilian.

Theſe topazes have all the characters of quartz.

Genus II. Flint, Agate.

Flints and agates form ſmall round maſſes, moſt commonly opake (though ſometimes ſemi-tranſparent), either hollow or ſolid, variouſly coloured and diſpoſed in ſtrata; in chalk, as is the caſe with flints; or in clay, as are the agates. Their fracture is ſometimes ſcaly.

Species.—1. Grey flint.
2. Yellow flint.
3. Red flint.
4. Corneous flint; gun-flint.
5. Brown flint; Egyptian.
6. Tranſparent ſpotted flint; German agate.
7. Red agate; Carnelian.
8. Pale red agate.
9. Brown or yellow agate; ſardonyx.
10. Onyx; concentric laminæ.
11. Laminated agate, diſpoſed in horizontal layers. Much of the appearance of the laminæ, and their diſpoſition relative to the figure of the ſtone, depends on the cutting.
12. Agate with figures. { Dendrites; herborized agates *.
Antropomorphites.
Zoomorphites.
Uranomorphites.
13. Agate apparently mouldy, or marked with ſmall greeniſh points, generally owing to moſſes.
14. Agate of four colours; elementary.
15. Grey agate; grey chalcedony.
16. White or milky agate chalcedony. { in beds.
in ſtalactites.
worn round; cacholong.

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* M. Daubenton has ſhown, in a memoir read to the Academy, that herborized ſtones contain very fine moſſes, or ſmall grains of black iron ore.

17. White agate, reflecting the light in a peculiar manner, called chatoyant.	Chatoyant agate of the lapidaries. Cat's eye. Oculus mundi, or hydrophane. Opal. Giraſol.

18. Brown agate, with brilliant gold-coloured ſpecks. Avanturine.

19. Oriental agate.

20. Agate encloſing water. *Enhydre.*

That the formation of quartz, agates, and flints, is owing to water, is evident from

1. Their form.
2. Their laminæ, or beds.
3. Their maſſes.
4. The water they contain.
5. The organic matters included in them, as in the moſſy or mouldy agates.

The hiſtory of the gæodes likewiſe proves this truth. Theſe are ſtony boxes filled with cryſtals, in which ſilex and quartz are found diſpoſed in concentric laminæ.

Genus III. Organic Matters converted into Silex, or Agate.

The organic form ſtill viſible, together with the characters of quartzoſe ſtones, diſtinguiſh them from all the other genera of this order *.

Species.—1. Petrified wood; ſtill fibrous, and ſuſceptible of poliſh.

2. Wood, whoſe ſpecies is diſtinguiſhable on account of its texture. Fir.

3. Sea urchins and madrepores, converted into ſilex.

4. Shells agatified.

5. Carpolites; theſe have been falſely regarded as petrified fruits; they are ſmall ludus helmontii ſilicified.

6. Entrochites.

7. Lapis frumentarius ſiliceus.

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* It would, perhaps, be much more natural to form a particular claſs of animal and vegetable ſubſtances, altered during their ſtay in the earth. This claſs might be named foſſils, and might be placed at the end of the organized kingdom. Note of the author.

It gives fire with the ſteel, does not efferveſce with acids, and ſeems to be formed by the aſſemblage of cornua ammonis, divided perpendicularly to their volutes.

There are two opinions concerning petrifaction. According to the one, the organized matters are entirely converted into ſtone. According to the other, the void ſpaces left in ſoft earths by animal ſubſtances, or the intervals in the texture of vegetable bodies, have been filled by the gradual depoſition of earthy matter. But there is nothing certain with regard to the cauſe of this phenomenon. It has been obſerved, that vegetable matters almoſt always become quartzoſe, while animal matters moſt commonly become calcareous; and that vegetables ſcarcely ever paſs into the calcareous ſtate, at the ſame time preſerving their texture*. This obſervation may ſuffice to ſhow, that there is no ſuch thing as petrifaction, properly ſo called, or real change of organized ſubſtances into ſtone. For, 1. Shells and madrepores ſuffer no other change than the loſs of their mucilage or animal gluten by putrefaction, and become thin calcareous ſkeletons, ſuch as they exiſted entire during the life of their inhabitants. 2. The pretended petrifactions of wood are nothing more than depoſitions of vitrifiable earth. In proportion as the fibres are deſtroyed by putrefaction, ſiliceous earth is depoſited in the cavity, which retains the organic figure; and at length, when no more vegetable matter is left, the petrifaction is completed.

GENUS IV. Jaſper.

Jaſper poſſeſſes all the characters of quartzoſe ſtones. It is not fuſible, but loſes its aggregation by heat. It is a very hard ſtone, ſuſceptible of a beautiful poliſh, opake, and variegated with different colours. Its fracture is vitreous and dull. It is very ſeldom ranged in ſtrata, but moſt commonly forms conſiderable maſſes or veins in rocks. It is alſo found in ſmall round maſſes. Moſt of the ſamples of jaſper are mixtures of quartz and chalcedony. Some contain calcareous ſpar.

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* Since the diſcovery of the fluoric acid gas, which has the property of depoſiting ſiliceous earth, ſome naturaliſts have thought that petrifaction is owing to a ſimilar phenomenon; but this opinion can be only regarded as an hypotheſis, till the exiſtence of an acid holding ſiliceous earth in ſolution in the bowels of the earth can be ſhown. Note of the author.

The ſpecies of jaſper have been greatly multiplied by naturaliſts. They may be reduced to the following:

Species.—1. White jaſper.
2. Grey.
3. Yellow.
4. Red.
5. Brown.
6. Green.
7. Veined.
8. Spotted.
9. Green, with red points. Blood ſtone.
10. Flowered.

Toys, and more eſpecially cups and ſaucers, are made of jaſper. Many antique ſculptures are in ſtones of this nature.

GENUS V. Grit-ſtone, or Free-ſtone.

Grit-ſtone is opake, of a granulated fracture, much leſs hard than quartz or flint. It exiſts in enormous maſſes, more or leſs hard, and of a grain coarſer or finer in different ſpecimens.

Species.—1. Grit-ſtone cryſtallized in rhomboids. M. de Laſſone has proved that their figure is a conſequence of their containing calcareous earth *.
2. Grit-ſtone in the form of cauliflowers, balls, &c.
3. Grit-ſtone in ſtalagmites.
4. White.
5. Grey.
6. Red.
7. Black, or brown.
8. Veined.
9. Figured, or dendritical.
10. ———, whoſe aggregation is deſtroyed; ſand.

The following are the varieties of ſand:

Varieties.—1. Quickſand.
2. Angular ſand.
3. Sand rounded by the action of water.
4. Pure white ſand.

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* Memoirs of the Academy of Sciences for the year 1777.

5. Micaceous ſand; glarea.
6. Yellowiſh ſand mixed with clay; founder's ſand.
7. Ferruginous ſand; yellow.
8. Ferruginous ſand; black.
9. Blue ſand; from copper.
10. Violet ſand; from tin.
11. Auriferous ſand.

ORDER III. Argillaceous Earths and Stones.

They have a greaſy feel; are kneadable; ſtick to the tongue when dry; are foliated; often coloured; are diſpoſed in beds or ſtrata, and in large maſſes.

Their aggregation is leſs ſtrong than that of quartzoſe ſtones. They have a greater tendency to combination, and are therefore moſtly altered. Heat cauſes them to contract in their dimenſions, and gives them ſo great a degree of hardneſs, that they emulate the quartzoſe ſtones, and, like them, give fire with the ſteel. Water reduces them into paſte, and in larger quantities divides them, and renders them pure by the mechanical ſubſidence of the groſſer ſubſtances they may contain. They retain water ſo ſtrongly, that they cannot be again totally deprived of it.

Part of their ſubſtance combines with acids. Some chemiſts have ſuppoſed that clay is nothing but the ſiliceous earth changed by the ſulphuric acid; but this opinion is not founded on any direct proofs.

Many naturaliſts have thought that vitrifiable earths, by long expoſure to external agents, water, air, and heat, become more and more divided, and are at laſt reduced to ſuch a degree of ſubtlety, as to be ſoft to the touch, and ſuſceptible of union with water; or, in a word, that they become clay. This theory, being founded on ſome accurate obſervations, ſeems to deſerve more confidence than the former; but neither the one nor the other are completely proved.

On the two properties of clay, namely, its ductility when ſoftened by water, and the hardneſs it acquires by baking, are founded the arts of making tiles, bricks, and all the varieties of pottery; the details of which belong to the hiſtory of theſe earths.

Naturaliſts have deſcribed a great number of ſpecies of argillaceous earths, and have confounded with them many which are not argillaceous, as well as certain compound ſtones, as ſerpentine, zeolite, trapp, &c.

The name of argill, or clay, ought not to be given to any earths but ſuch as harden in the fire, are kneadable with water, and form alum with the ſulphuric acid.

M. Macquer, who has examined a great number of clays *, found none abſolutely pure. The colour and fuſibility of many of the ſpecimens are owing to the admixture of different combuſtible and metallic ſubſtances.

The late M. Bucquet diſtinguiſhed them into four genera.

GENUS I. Soft and ductile Clays.

They may be kneaded when firſt dug out of the earth; they become dry in the air.

Species.—1. White clay; pipe clay.
2. Sandy clay.
3. Ductile blackiſh clay; for white pottery.
4. Clay with mica, kaolin; partly fuſible; for porcelain.
5. Metallic clay; fuſible; ſealed earth, Armenian bole.
6. Pyritous clay; fuſible; blue, green, or marbled; for common pottery.

GENUS II. Dry friable Clays, Tripolis.

All the clays which M. Bucquet ranked among the tripolis, are found dry in the earth. They are all formed in beds or ſtrata, frequently very thin. They all wear away by rubbing with the finger, and are reduced into powder. They imbibe water with great avidity, and ſtick to the tongue.

1. Dry, grey, foliated clay; fuller's earth.
2. Red tripoli. Some ſuppoſe it to be a volcanic production.
3. Grey tripoli.
4. Black tripoli.
5. Rotten ſtone; of an olive grey.

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* *Academie des Sciences*, 1758.

GENUS III. Schiſti.

The ſchiſti are laminated ſtones, which eaſily ſplit into plates; they are very much compounded, and fuſible. They form large blocks, placed with various degrees of obliquity in the interior parts of the globe. Almoſt all the quarries of this ſubſtance have impreſſions on their upper ſurfaces, of parts of plants, of the claſſes of ruſhes, fern, &c. and of ſhells, fiſhes, inſects, &c.

Species.—1. Black ſchiſtus, friable; ampelite.
2. Fiſſile ſchiſtus, ſlate.
3. Black ſchiſtus, hard, ſlate for writing.
4. Red, brown, &c. ſchiſtus.
5. Schiſtus, with vegetable and animal impreſſions.
6. Very hard ſchiſtus, for ſharpening razors.

GENUS IV. Feld-Spar.

It is formed by rhomboidal laminæ; its fracture is ſpathoſe; it gives fire with the ſteel; whence it has been called ſpatum ſcintillare. It is harder than the ſchiſti, and is fuſible. Mr. Bucquet thought it to be an argillaceous ſtone, coloured by iron. M. Monnet ſays, it is compoſed of quartz, clay, magneſia, and a ſmall portion of calcareous earth. The difference of opinions reſpecting the nature of feld-ſpar, ariſes from its not being yet well known. Future experiments may ſerve to fix its place *.

Species.—1. Priſmatic feld-ſpar †.
2. White feld-ſpar.
3. Red feld-ſpar.
4. Green feld-ſpar.
5. Blue feld-ſpar.

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* Father Pini, an Italian naturaliſt, is the firſt who diſcovered the feld-ſpar in a cryſtallized form. Since his time, it has been found in many parts of France, particularly at Roanne in Forez, where they are very regular. I have given a full deſcription of the feld-ſpar found in the granites of Alençon, which is one of the moſt regular and beautiful I know. See my *Memoires de Chimie*. Note of the author.

† M. Daubenton has placed it among the ſcintillating ſtones. Three characters diſtinguiſh it from every other kind of ſtone. Its texture is ſpathoſe; it is chatoyant; and it gives fire with the ſteel. From theſe characters, this genus ought to contain more ſpecies than the late M. Bucquet attributed to it. M. Daubenton reckons the fiſhes eye, the avanturine, the Labrador ſtone, &c. of this genus. See his tables. Note of the author.

ORDER IV. False Clays.

They reſemble clays only in their foliated texture, and greaſy appearance; ſome harden in the fire.

They differ from clays, in not making a paſte with water; and moſt part of them melt in the fire. With the ſulphuric acid, they afford a ſalt in needles, which does not change in the air, is ſoluble in four or five times its weight of water, and does not ſwell in the fire. In a word, it is not alum. Theſe characters have been given by M. Bucquet, who examined many of theſe ſtones. But as they are yet very little known, they may be placed after the clays. The Abbé Mongez obſerves, in his introduction to the *Sciagraphia* of Bergman, that theſe ſtones would be more properly termed magneſian. I am much inclined to adopt this nomenclature; but more numerous experiments ſeem to be neceſſary, before this name can be unalterably fixed.

Genus I. Lapides Ollares, hard.

Their texture is ſcarcely at all foliated; their appearance is greaſy; they take but a bad poliſh.

Species.—1. Grey lapis ollaris from Sweden.
2. Greeniſh colubrine of Sweden.
3. Yellowiſh ſoap-ſtone of China.
4. Brilliant green; jade. The lapis nephriticus, and thoſe of Otaheite, were varieties of jade, according to M. Bucquet. We may obſerve that jade is very hard, and gives fire with the ſteel. It is doubtleſs after Pott, that M. Bucquet placed it among the lapides ollares.
5. Dirty green lapis ollaris. Colubrine.
6. Serpentine. A ſtone of deep green, or blackiſh colour, with black ſpots or veins, like the ſkin of ſerpents. We have placed it at the end of the lapides ollares, on account of its aſpect, though it ſeems to be a compound ſtone.

Genus II. Tender Lapides Ollares, Steatites or Smectites.

They have a more ſoapy feel than the preceding. They are very eaſily cut; they lather with water; ſome kinds have a ſtriking reſemblance with ſoap.

Species.—1. White ſteatites, compact; Briançon chalk.
2. Brilliant or glittering Briançon chalk. Venetian talc of the druggiſts.
3. White ſteatites from Norway.
4. Red marbled ſteatites from Norway.
5. Reddiſh ſteatites from Norway.
6. Green compact ſteatites from Norway.
7. Green and red ſteatites from Norway.
8. Green ſteatites, foliated; tender colubrine from Norway.
9. Black ſteatites.
10. Grey and brilliant ſteatites, plumbago, molybdena, and improperly black lead. This being pulverized, and made into a paſte with iſinglaſs, is encloſed in ſmall wooden cylinders, which are cut to a point at the end, and uſed as crayons or pencils*. The Engliſh pencils are made of plumbago alone.

GENUS III. Talc.

It is compoſed of poliſhed and glittering laminæ, of a jelly-like tranſparency, applied one on the other. It appears that theſe laminæ are ſometimes cryſtallized in hexagons, or ſections of ſix-ſided priſms. By a violent fire it melts into a coloured glaſs.

Species.—1. Talc in large tranſparent plates; Muſcovy glaſs.
2. Talc in very ſmall ſilvery white ſpangles.
3. Talc in very ſmall gold-coloured ſpangles.
The two laſt mentioned are uſed as writing ſand, under the name of ſilver or gold duſt.
4. Talc worn into the form of pebbles.
5. Talc in black ſpangles.
6. Talc in mixed brilliant ſpangles.

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[*] Since the death of M. Bucquet, and the firſt impreſſion of this book, Meſſrs. Scheele, Gahn, and Hielm, have made very ſucceſsful reſearches into the nature of plumbago. They have diſcovered that this ſubſtance is a kind of ſulphur, formed, according to them, by the combination of the aerial or carbonic acid with phlogiſton. We ſhall give its hiſtory in that of iron. The ſame chemiſts, and eſpecially M. Scheele, have made a proper diſtinction between molybdena and plumbago; which naturaliſts have, till lately, confounded together. Molybdena is regarded by Scheele as a compound of ſulphur and a peculiar acid, which he called the acid of molybdena. (See the Hiſtory of Sulphur.) It is the plumbago which is uſed for crayons. Note of the author.

GENUS IV. Amianthus, Aſbeſtos.

This genus of ſtones is formed of fibres or threads placed parallel to each other, or interlaced together like tiſſue; the fibres are either rigid or flexible, and differ from each other in thickneſs, length, and colour. The ancients wove them into a cloth, which was called incombuſtible linen, and uſed to envelope their dead when burned on the funeral pile. It ſerved to retain and collect their aſhes, &c.

By a violent fire, amianthus is eaſily melted into a coloured opake glaſs.

Species.—1. Aſbeſtos, hard and grey, with parallel fibres; ligneous aſbeſtos.

2. ———, hard and green in parallel fibres.

3. ———, hard and green, with fibres in bundles.

4. ———, with diverging fibres.

5. ———, with ſoft fibres.

6. Amianthus, hard, with parallel greeniſh fibres.

7. ———, hard, with parallel white fibres.

8. ———, with white brilliant fibres in bundles.

9. ———, in hard bundles, yellowiſh.

10. ———, white and flexible.

11. ———, grey.

12. Mountain fleſh.

13. ——— leather.

14. ——— cork.

SECTION II.

Compound Earths and Stones.

They are not diſtinguiſhable by the eye from thoſe of the preceding ſection. As to their characters, they are formed of matter apparently homogeneous, almoſt always coloured, moſtly opake, but ſometimes tranſparent, and moſt ſpecimens are regularly cryſtallized. Their form and colour ſerve to diſtinguiſh the genera. They are all very fuſible, and afford different kinds of glaſſes. Their fracture is ſometimes vitreous, ſometimes ſcaly. In theſe ſubſtances it is that nature has combined earths, ſalts, and metals together.

M. Bucquet divided theſe ſtones into two orders. In the firſt were comprehended earths and ſtones, compoſed by water, to which he gave the characters proper to the products of that element. He divided this order into two genera, namely, ochres and zeolite. In the ſecond, he placed ſchorl, macles, trap, azure ſtone, the fuſible precious ſtones, volcanic cryſtals and glaſſes, and pumice ſtones. He regarded theſe eight kinds of ſtones as the products of fire. We have conſidered it as our duty to exhibit the ideas of this celebrated chemiſt; but as the diſtinctive characters of theſe two orders are not yet eſtabliſhed on numerous and concluſive proofs, and as M. Bucquet himſelf propoſed them as mere ſketches, we ſhall here give the hiſtory of the ſeveral kinds in ſucceſſion, without adhering to his method of diviſion.

GENUS I. Ochres.

Ochres are leſs acted on by water than clays. They are friable, and ſoil the fingers; their colour is cauſed by metallic ſubſtances, almoſt always iron. When urged by fire, their colour becomes more intenſe. A violent heat melts them. They are uſed as pigments.

Species.—1. Yellow ochre.
2. Red ochre, blood colour.
3. Green ochre; earth of Verona.
4. Brown ochre; umber.

GENUS II. Zeolite.

Zeolite, firſt deſcribed by Cronſtedt, is a ſtone compoſed of needles diverging from a centre, or even of detached cryſtals. It neither gives fire with ſteel, nor effervefces with acids. Expoſed to the action of fire, it ſwells up, and affords a white glaſs reſembling enamel. By diſtillation it affords much water. The reſidue contains, according to Bergman, ſiliceous, aluminous, and calcareous earths. M. Bucquet, who likewiſe made the analyſis of this ſubſtance, affirms, that he found very little ſiliceous earth, and a peculiar earth, which is neither aluminous nor calcareous, but forms with the ſulphuric acid a cryſtallizable ſalt in ſmall ſhining plates, reſembling the boracic acid ſalt, which he has thought proper to call zeolitic earth. Theſe two earths are cryſtallizable together by the aſſiſtance of water, which makes more than one eighth of the whole compoſition. M. Bucquet obtained one drachm and a half of water from an ounce of the white zeolite, of the Iſland of Ferro *. The property of forming a jelly with the different acids is not peculiar to this ſubſtance, but is common to the azure ſtone, tin, and to ſeveral ores of iron, &c. Its origin and formation are unknown; but it is abundantly found among the products of volcanos. It is very plentiful in the Iſland of Ferro. We are acquainted with ſix ſorts.

Species.—1. White zeolite in tranſparent faſces.
2. White zeolite in compact faſces.
3. Red zeolite.
4. Green zeolite.
5. Blue zeolite.
The red, green, and blue, have not been examined †.

GENUS III. Schorl.

Schorl is a ſtone of a more or leſs dark colour, cryſtallized, and varying in its figure, moderately brittle, and giving fire with ſteel. It readily melts into a black opake glaſs. According to M. Bucquet, it contained alumine and iron in combination. Bubbles have been obſerved in the internal part of ſchorls, ſimilar to thoſe in the ſlags at glaſs-houſes.

Its origin is not well known. Some perſons regard it as a volcanic product, becauſe it is frequently met with in places which have been burned; but it is likewiſe found among matters formed by water.

Species.—1. Violet ſchorl, cryſtallized in flat rhomboids.
2. Violet, in fibrous maſſes.
3. Black, in priſms of four, ſix, eight, or nine ſides; with pyramids of two, three, or four faces, like the violet ſchorl.
4. Black ſchorl in maſſes.
5. Green ſchorl in lamellated maſſes.

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* *Memoires des Savans Etrangers*, Tom. IX. page 576.

† M. Pelletier, the pupil of M. d'Arcet, has given (*Journal de Phyſique*, 1782, p. 420.) a memoir on the analyſis of the zeolite of Ferro. By very accurate experiments he found that 100 grains of this ſtone contain 20 of pure clay, 8 of lime, 50 of ſiliceous earth, and 22 of water. Note of the author.

6. White bluiſh ſchorl.
7. Electric ſchorl of a reddiſh yellow, tourmaline.

GENUS IV. Macles.

By this name we underſtand certain priſmatic opake ſtones, of a dirty appearance, often regularly formed. Their analyſis made by M. Bucquet, ſhows that they approach the nature of ſchorls. They are compoſed of iron and clay.

Species.—1. Tetrahedral macle, whoſe ſection ſhows the figure of a croſs. It is found in a kind of hard, deep blue ſchiſtus of Brittany; it is very adheſive, and very brittle. When broken, two bluiſh lines are ſeen on its tranſverſe ſection, interſecting each other in the middle, and forming a croſs. Sometimes the middle of the priſm appears to be filled with a matter ſimilar to that of the gangue.

2. Croſs-ſtones. Hexahedral priſms, articulated and croſſed in the middle like the arms of a croſs. They are found in the leaves of yellow mica. The two branches ſcarcely ever croſs each other at right angles.

GENUS V. Trap.

Trap is a hard ſtone, of a fine grain, of a foliated fracture, with angular indentations like ſteps. It is of a deep blackiſh green, often inclining to the colour of ochre: Sufficiently hard to give fire with ſteel; and affords a blackiſh glaſs in the fire. It is always covered with a kind of matter leſs hard than its own ſubſtance. Its component parts, according to M. Bucquet, are clay and iron, the latter being in the proportion of twenty-five pounds per quintal; ſo that it may be ranked among iron ores. M. Daubenton conſiders it as a ſchiſtus containing quartz in ſand. We know but of one kind of trap, which is that above deſcribed.

GENUS VI. Azure Stone; Lapis Lazuli.

Its colour, the fineneſs of its grain, the analyſis, which ſhows that this ſtone contains iron, are reaſons for placing this immediately after the foregoing. There are three ſpecies.

Species.—1. Oriental azure ſtone.

2. Azure ſtone of a pale blue, frequently inclining to purple.

3. Armenian ſtone, ſpotted with white and pale blue.

The beautiful blue called ultramarine, which is uſed by painters, and is one of the moſt unchangeable we are acquainted with, is prepared from this ſtone.

GENUS VII. Fuſible Cryſtals, called Gems.

The chemical differences obſerved between the ſeveral kinds of precious ſtones or gems, induced M. Bucquet to ſeparate them from each other, and to claſs each in the order or ſection to which it ſeemed to belong. Thoſe which are ranked in this place are evidently of a compound nature. M. Bergman found them to contain many ſubſtances, ſuch as ſiliceous earth, clay, lime, and iron. They are all fuſible, and of a laminated ſtructure. Their fracture is lamellated.

Species.—1. Aqua-marine.

2. Emeralds.

3. Chryſolite.

4. Ruby.

5. Bohemian garnet.

6. Garnet.

GENUS VIII. Volcanic Cryſtals.

In this genus M. Bucquet comprehended all regular formed ſtones, tranſparent and coloured like the gems, but which have neither their hardneſs nor brilliancy. They are found in cavities lined with ſmall brilliant particles of the ſame nature agglutinated together. They are met with in the neighbourhood of volcanos. We admit three ſpecies.

Species.—1. Volcanic chryſolite; polyhedral cryſtals of a golden green.

2. Volcanic hyacinth; polyhedral cryſtals of orange yellow.

3. Volcanic garnets. They greatly reſemble ſingle garnets; but they are irregular, and ſcattered among, or on the ſurface of, brilliant lavas, together with the two foregoing.

GENUS IX. Pumice Stones.

Moſt of the pumice ſtones appear to conſiſt of an aſſemblage of vitreous fibres, like threads wound on a clue. Their ſubſtance is a true combination of various matters fuſed by volcanic fires.

Pumice ſtones may be diſtinguiſhed into four kinds, each of which has many varieties.

Species.—1. White fibrous pumice ſtone.
2. Coloured fibrous pumice ſtone.
3. Cellular and light pumice ſtones.
4. Cellular and compact pumice ſtone.

GENUS X. Volcanic Glaſs.

The glaſſes melted and ejected by volcanos are formed of earthy and ſaline matters, coloured by iron, or other metallic matters. They are true chemical combinations performed by nature in the dry way.

Species.—1. Cellular greeniſh glaſs.
2. Blackiſh glaſs; cellular, or in agglutinated fibres.
3. Beautiful black tranſparent glaſs, Iceland agate, lapis obſidianus of the ancients.

SECTION III.

Mixed Earths and Stones.

It is very eaſy to obſerve the leading character of the ſtones of this ſection, as mere inſpection is ſufficient to ſhow the different matters which compoſe them, eſpecially if they be properly compared with the varieties of the preceding ſections. We have already remarked, that mechanical ſeparation of their ſeveral parts is firſt required before the chemical analyſis can be undertaken. By this we find ſimple united with compound ſtones. If theſe mixed ſtones be expoſed entire to the action of fire, they melt with more or leſs facility into glaſſes of different colours and appearance, according to the nature of the parts which compoſed the mixture.

They appear to have been formed by the junction of the different ſubſtances we ſee; and this junction muſt have been made either by means of water or fire. This laſt conſideration engaged

M. Bucquet to divide this ſection into two orders like the foregoing. The firſt order comprehends the mixed ſtones formed by water; and the ſecond, ſuch as have been compoſed by fire. This diviſion being founded on a much greater number of facts than the preceding, induces us to admit it with much more confidence.

ORDER I. EARTHS AND STONES OF A MIXED NATURE, FORMED BY WATER.

GENUS I. Petro-ſilex.

By this name naturaliſts denote a ſtone of an intermediate hardneſs between the ſofter ſtones and thoſe of the ſiliceous order. M. Daubenton has placed it among the vitreous ſtones, becauſe it gives ſparks with the ſteel, and its fracture is vitreous, though rather ſcaly. Petro-ſilex has a ſemi-tranſparency reſembling wax. It is dull, and not at all ſhining, but rather of the aſpect or defective kind of poliſh which tallow uſually has. Its grain is fine, and very cloſe. It is found in very large maſſes, and often in beds or ſtrata of different ſhades, lying above each other. M. Bucquet gives us its chemical character; that of melting by fire into an opake glaſs. Its mixture is very far from being as evident to inſpection as that of the following genera. It ſeems to have the ſame characters as the compound ſtones *, and is, for that reaſon, placed at the head of this third ſection. It ſerves, as it were, as a connecting link between the two.

The form of its beds, the matters it frequently contains, and eſpecially the maſſes of it, which are placed in the bowels of the earth, ſhow that it is formed by means of water.

Species.—1. Grey petro-ſilex.
2. Reddiſh.

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* It is neceſſary to obſerve that theſe characters, founded on the action of fire on ſtones, are eſtabliſhed by experiments made by the Duc de la Rochefoucauld, and by M. Bucquet, in an excellent melting furnace conſtructed for that purpoſe in the laboratory which the diſtinguiſhed encourager of the ſciences here mentioned has devoted to every kind of reſearch that may tend to the advancement of chemiſtry. I have examined moſt of thoſe reſults, which will doubtleſs be communicated to the learned world. This communication will confirm the valuable ſeries of experiments made by M. d'Arcet, with the addition of many facts ſerving to eſtabliſh the chemical characters propoſed by M. Bucquet to be uſed in the claſſing of ſtones. Note of the author.

3. Greeniſh.
4. Brown.
5. Black.
6. Spotted.
7. Veined.

GENUS II. Pudding Stone.

Pudding ſtone is a mixture of flints connected by a cement of a different nature. This cement is either of the nature of freeſtone, or argillaceous, or ochreous. It is ſometimes hard, and reſembles ſilex.

It is not at all doubtful but its formation is effected by water. It is always found on the ſea coaſts, or in places which have been covered by water, and afterwards deſerted by that element.

Species.—1. Sandy pudding ſtone.
2. Ochreous.
3. Argillaceous.
4. Siliceous.
5. Agatified; ſuſceptible of the fineſt poliſh.

GENUS III. Granite.

Granite is formed of three ſtony matters in fragments of greater or leſs magnitude united together. Theſe three ſubſtances are quartz, feld-ſpar, and mica.

It gives fire with ſteel, on account of the quartz and feld-ſpar it contains; its fracture is irregular, and very coarſe grained; it is fuſible, but in different degrees, according to the reſpective quantities of the matters which compoſe it; it takes a poliſh more or leſs bright, according to the fineneſs of its grain, and the hardneſs of the principles which enter into its compoſition. Some ſpecimens change by expoſure to the air. This laſt phenomenon has ſerved to diſtinguiſh the ancient from the modern granites. The ſpecies of granite have been greatly multiplied *. They may, however, be reduced to the following:

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* Modern philoſophers have paid great attention to the natural hiſtory of granite. M. de Sauſſure has given much new and important information on this ſubject in his *Voyage des Alpes*. All granites are not formed by the mixture of the three ſtones mentioned in the text. There are ſome which contain ſchorl inſtead

Species.—1. White granite.
2. Grey.
3. Red.
4. Brown.
5. Green.
6. Black.
7. Dull and friable; altered by expoſure to air.

GENUS IV. Porphyry.

Porphyry is a ſtone covered with ſpots in a ground of a red or other colour. It gives many ſparks with the ſteel.

It differs from granite by its greater hardneſs, and its being ſuſceptible of a much more lively poliſh. It appears to be formed of feld-ſpar and ſchorl united by a quartzoſe cement.

The cement or paſte, which forms the baſis of porphyry, is of a very fine and cloſe grain. The different fragments, which are bedded in this ground, are in general much ſmaller than thoſe of granite. This ſtone is fuſible, and affords a coloured glaſs. All the ſpecies of porphyry may be reduced to the ſeven following;

Species.—1. Red porphyry, with large ſpots.
2. ————, with ſmall ſpots.
3. Green porphyry, with large ſpots.
4. ————, with ſmall ſpots.
5. Black porphyry, with large ſpots.
6. ————, with ſmall ſpots.
7. Coarſe porphyry of a dirty red, almoſt without ſpots, approaching to the nature of ſand-ſtone.

GENUS V. Ophites, or Serpentine.

Pliny gives the name of ophites to ſtones ſpotted like the ſkins of ſerpents. M. Bucquet conſidered them as ſpecies of porphyry; but harder, more ancient, and of a mixture much more intimately combined. The name of ſerpentine, or hard ſerpentine, has been given to them. On comparing this ſtone with porphyry, it is ſeen that ſerpentine, as well as porphyry, is compoſed of a quartzoſe paſte, together with feld-ſpar and ſchorl, but that the

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of mica; others contain both ſchorl and mica. The mixture of quartz and feld-ſpar only is called granitin; and the ſtone compoſed of quartz and ſchorl is called granitello. See De Sauſſure's *Voyages dans les Alpes*. Note of the author.

feld-ſpar in the former is in large rhomboidal fragments, while it is very ſmall in the porphyry.

Serpentine gives ſparks with ſteel. Its fracture is fine, and rather ſcaly. It melts in the fire.

The following are the principal ſpecies of ſerpentine we have ſeen.

Species.—1. Ophites of a deep green colour, with large white ſpots.

2. Ophites of a deep green colour, with oblong pale green ſpots.

3. Ophites ſimilar to the foregoing, but with very ſmall, and ſcarcely perceptible ſpots. Many ſavage nations cut them into coins. They have been called thunder-ſtones.

4. Ophites of a brown colour, with irregular oblong ſpots of a roſe coloured white.

The origin of ophites is very obſcure. It is not well known whether they are the product of water, or of fire. As they have ſome analogy with porphyry, we have placed them after that ſtone.

ORDER II. EARTHS AND STONES OF A MIXED NATURE FORMED BY FIRE.

[*Continuation of the Volcanic Products.*]

There is no diſpute concerning the origin of ſubſtances which compoſe this order, ſince they are never found but in the neighbourhood of volcanos, or in places where volcanos have formerly exiſted: beſides which, they exhibit all the characters of products of fire. By joining the genera of this order with thoſe deſcribed among the compound ſtones, a complete ſeries of volcanic products will be had.

We ſhall not comprehend under the name of volcanic products all the ſtones or earths found in the neighbourhood of volcanos, which are not at all altered by fire; as is the caſe with the greater part of the ſtones we have already deſcribed, eſpecially granite, clays, &c. as well as many ſaline ſubſtances, together with calcined, melted, ſublimed, or vitrified matters. It would be an uſeleſs repetition to take notice of their hiſtory in this place. We ſhall elſewhere take notice of their exiſtence in the neighbourhood of volcanos, and the changes produced in them by the ſubterraneous fires.

GENUS I. Volcanic Aſhes.

The name of volcanic aſhes has been improperly given to certain pulverulent earthy matters found near volcanos. They appear to owe their origin either to the ſubſtances mixed and thrown out by volcanos, or to lavas altered by the contact of air and water. M. Bucquet conſidered them as combinations of clay and iron. They frequently obey the magnet. We are acquainted with two ſpecies.

Species.—1. Rapillo; a pulverulent matter of a blackiſh grey, found near the craters of volcanos.

Rapillo contains garnets and ſchorls, whoſe form is diſtinguiſhable, though their angles have been ſoftened and encruſted apparently by ſome matter in fuſion.

2. Puzzolana. This ſubſtance is named from the town of Puzzoli, where it was very anciently made uſe of. It is an argillaceous earth, charged with iron, and of different colours, according to the ſtate of the metal. It is found of a grey, yellow, red, brown, or black colour. By fire it melts into a black enamel. The great utility of this ſubſtance conſiſts in its forming a kind of mortar, which has the property of becoming hard in water. M. Faujas de St. Fond has found it in Vivarais. He thinks that theſe earths are formed by the alteration and deſtruction of the porous lavas, and even of the baſaltes. This philoſopher, in his reſearches concerning puzzolana, has given a detail of the proceſſes for conſtructing edifices both in the air and under water with this ſubſtance.

GENUS II. Lavas.

This name is given to the melted and ſemi-vitrified matter of volcanos. They moſt commonly flow down the ſides of mountains, whoſe internal parts are on fire, and form rivers of burning matter, which ſometimes flow to prodigious diſtances, to the deſtruction of every thing in their way. Their heat and maſs are ſo conſiderable, that they are ſeveral years in cooling. During this period, they crack and ſeparate into maſſes, which are ſometimes regularly formed. Such appears to have been the origin of baſaltes. A great variety of theſe ſtones are found in cabinets of natural hiſtory. They are in general compoſed of a paſte of a grey colour, more or leſs deep, with great varieties of texture and hardneſs, in which are bedded cryſtals, or irregular fragments of ſchorl, garnet, glaſs, zeolite, &c. conſtituting a true mixture. It is impoſſible to give any general character of lavas, as they all differ in their grain, conſiſtence, hardneſs, colour, mixture, &c. In general they are very fuſible, and afford a kind of black enamel, ſimilar to the glaſs of volcanos. M. Cadet has found them to contain clay, iron, copper, and quartz. Bergman thinks them to be compoſed of ſiliceous, argillaceous, and calcareous earths, with iron. Many, and more eſpecially the compact lavas, have the property of acting on the magnetic needle.

Species.—1. Soft lava of various colours, with cryſtals of black ſchorl.
2. Soft lava of various colours, with cryſtals of green ſchorl.
3. Soft lava of various colours, with cryſtals of white ſchorl.
4. Reddiſh lava, with blackiſh cryſtals.
5. Yellowiſh and ſaline lava.
6. Soft lava with cryſtals of garnet.
7. Chatoyant and porous lava.
8. Porous, grey lava.
9. Soft lava, blackiſh, with white cryſtals.
10. Grey lava, rather compact, interſperſed with opake, dodecahedral cryſtals, or garnets altered by fire.
11. Ancient lava, very compact, of a blackiſh grey, with ſpots of a deeper colour.

GENUS III. Baſaltes.

The deſcriptions given by naturaliſts of baſaltes, are very far from being exact. Many confound ſchorls and garnets with the true baſaltes, and no writer has given a good definition of the word. Some regard this ſubſtance as a volcanic product; others have ſuppoſed them to be formed by water. We think it proper, in conſequence of the valuable obſervations of Meſſrs. Deſmarets and Faujas de Saint Fond, to adopt the former opinion.

We may aſſume the following as the diſtinctive characters of baſaltes. A regular form; a perfect opacity; hardneſs ſufficient to give fire with the ſteel; cinereous grey colour inclining to black, and a manifeſt mixture of ſchorl or ſmall vitrified fragments, uſually of a deeper colour than the ground. The baſaltes are fuſible.

Some ſtones of this kind are of enormous magnitude, and exiſt in very conſiderable maſſes, whoſe formation ſeems to have been effected in times of the remoteſt antiquity. Such are, 1. The Giants Cauſeway, in the county of Antrim, in Ireland. 2. The Rock of Pereneire, near Saint-Sandoux, in Auvergne, well deſcribed by M. Deſmarets. There are others regularly cryſtallized in ſmall priſms of three, four, or five ſides, &c. Their figure, magnitude, and diſpoſition is exceedingly various.

In general, theſe ſtones are ranged ſymmetrically, one beſide another. Their analyſis does not appear to have been yet made with ſufficient accuracy to authoriſe any decided account of their nature. They ſeem to be nothing elſe but lavas, apparently cryſtallized in conſequence of the cracks formed in them in every direction during their cooling. The ſingular varieties they offer, and their arrangement, ſeem to give much force to this opinion. Water ſeems to have inſinuated itſelf into theſe clifts, and to have there depoſited various earths, at the ſame time that it has produced ſome alteration on the correſpondent ſurfaces of the baſaltes. This is apparently the cauſe of the yellow or brown cruſts which ſeem to envelope them.

Species.—1. Baſaltes in very long polygonal priſms, without regular pyramids.
2. Baſaltes in ſhort priſms, truncated with three, four, five, or ſeven facets.
3. Baſaltes in ſhort polygonal priſms, terminated by a concavity above, and a convexity below. Articulated baſaltes.
4. Small quadrangular, triangular, &c. Baſaltes formed by the fractures of the larger, and grouped with them *.

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* For the hiſtory of theſe ſtones, and of all the products of volcanos, ſee the excellent work of M. Faujas de Saint Fond, entitled *Minéralogie des Volcans*. Paris, 1784.

GENUS IV. Scoriæ of lavas.

The melted matter which conſtitutes lavas, is a mixture of many heterogeneous ſubſtances, differing in denſity and weight. During its cooling theſe ſeparate in the order of their ſpecific gravities. The ſcoriæ of lavas are bodies frequently of a ſpongy nature, which not having ſuffered as complete a fuſion as the lava itſelf, riſe above it by their comparative levity. In other reſpects they ſeem to be of the ſame nature, except that their principles are leſs perfectly mixed together. Cryſtals of ſchorl and granite are found in them as well as in the lavas themſelves.

Species.—1. Heavy volcanic ſcoriæ of a compact texture.
2. Black and cellular volcanic ſcoriæ.
3. Black and ſpongy volcanic ſcoriæ.
4. Black volcanic ſcoriæ, with twiſted fibres.
5. Yellow and ochraceous volcanic ſcoriæ.
6. Reddiſh volcanic ſcoriæ.

The two laſt have been manifeſtly altered by the contact of air, water, and acid vapours.

Such was the method in which the late M. Bucquet thought proper to claſs earths and ſtones in 1777 and 1778. Mineralogical chemiſtry has been greatly improved ſince that time. The analyſis of ſtones has been made in almoſt every chemical laboratory. Meſſrs. Bayen, D'Arcet, Monnet, De Morveau, Sage, Mongez, Pelletier, in France; Scheele and Bergman, in Sweden; Achard, Bindheim, and Hupſch, at Berlin; Woulfe, Withering, and Kirwan, in England, have examined a great number of ſtones and earths, and in conſequence of theſe numerous analyſes, the claſſification of theſe ſubſtances has ſuffered great changes; and two of the above-mentioned chemiſts have thought proper to publiſh ſyſtems of mineralogy, founded on the principles of bodies. But they have purſued a very different courſe from that of M. Bucquet, whoſe aim was to aſſociate the external characters with the chemical properties. Meſſrs. Bergman and Kirwan have paid ſcarcely any regard to the phyſical qualities in the claſſification of earths and ſtones. The nature, quantity, and proportion of their conſtituent parts have determined them in their methodical diſtribution. Their ſyſtem, though very uſeful in the promotion of chemical knowledge, cannot anſwer the purpoſe of diſtinguiſhing ſtones by their aſpect and ſenſible characters. It therefore appeared neceſſary to prefix to thoſe ſyſtems a natural method, as we have here done, with the intention, that each ſhould illuſtrate the other to the advantage of ſuch as undertake the ſtudy of minerals.

§ 11. *The Chemical Diſtribution of Earths and Stones, according to Bergman* *.

After ſhowing that the external characters are not ſufficient to diſtinguiſh minerals from each other, though they may be of great aſſiſtance when judiciouſly choſen, Bergman eſtabliſhes his principal diviſions of claſſes and genera on the compoſition and internal characters of the bodies. The principle, which is either the moſt abundant or the moſt active, in any mineral, is made uſe of as a guide in its diſtribution. He divides all minerals or foſſils into four claſſes, namely, ſalts, earths, bitumens, and metals. We ſhall only take notice of the earths in this place.

Bergman admits of five earths, ſimple and different from each other; namely, ponderous earth, lime, magneſia, clay, and ſiliceous earth †.

He firſt examines each of theſe earths in a ſtate of purity, though they are never found ſo in nature. He remarks, that theſe five earths combined together may afford twenty ſpecies, viz. ten combinations of two; ſix of three; three of four; and one of the whole five. But as he ranks among the earths ſuch of their combinations with acids as are not ſoluble in one thouſand times their weight of boiling water, the number of ſpecies is greater on this account. Beſides which, two earthy compounds conſiſting of like principles, may differ greatly in the proportion of theſe principles, and therefore have very diſtinct and different properties belonging to their reſpective combinations. Such are the grounds of diſtinction of the ſpecies admitted by Bergman, and by his commentator M. l'Abbé Mongez, who has made large additions to the labours of the Swediſh chemiſt. Here follows the ſpecies of each primitive earth according to this method.

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* The author in a note obſerves, that he has made uſe of the French edition of Bergman's *Sciagraphia Regni Mineralis*, tranſlated by Mongez. The Engliſh reader may recur to a tranſlation of this excellent ſmall work, publiſhed in London by Dr. W. Withering. T.

† Among theſe five earths, three have evident ſaline properties; namely, the ponderous earth, lime, and magneſia; and for that reaſon we ſhall give their hiſtory in the ſecond part of our work. Bergman, whoſe intention was to divide ſtones according to their principles, was neceſſitated to rank them among the earths, becauſe they are often united with each other. Many ſubſtances which this illuſtrious chemiſt has reckoned among the earths, are ſalts in our method. Note of the Author.

Ponderous Earth *.

Species I. Pure ponderous earth; it does not exiſt in nature, and is obtained by the decompoſition of the ponderous ſpar, as we ſhall ſee hereafter.

Species II. Aerated ponderous earth, or the combination of the ponderous earth with the aerial acid. It has not hitherto been found in nature: Bergman thinks it may be met with diſſolved in water †.

Species III. Vitriolated ponderous earth; ponderous ſpar; or the combination of the vitriolic acid with ponderous earth. This ſubſtance is abundantly found in mines. The Bolonian ſtone is a variety of this.

Species IV. Vitriolated ponderous earth, penetrated with petroleum, mixed with ſelenite, alum and ſiliceous earth; hepatic ſtone of Cronſtedt. This ſubſtance is ſpathoſe and brilliant; yellow, brown, or black; its odour is very ſtrong, and it does not effervefce with acids. A centenary of this natural compound contains, according to the analyſis of Bergman, 33 parts of ſiliceous earth, 29 of pure ponderous earth, and 5 of clay, beſides lime, water, and vitriolic acid ‡.

Lime.

Species I. Pure lime, or quicklime. Bergman did not know of its exiſtence in nature.

Species II. Aerated lime. Chalk, or calcareous earth. The combination of lime with the aerial acid. It is rarely pure. It often contains the marine ſalt of magneſia, calcareous marine ſalt, clay, ſiliceous earth or iron. Within, or at the ſurface of the earth, it conſtitutes lac lunæ, ſtony icicles, calcareous ſtones, marbles, calcareous ſpars, concretions, or ſtalactites, &c.

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* In this detail we follow the denominations given by Bergman: It will be eaſy to refer the ancient names, whether of the earthy baſes or the acids united to them, to the new and methodical denominations given to thoſe bodies in the hiſtory of ſaline matters in the body of the work. Note of the author.

† The aerated ponderous earth was found in England ſince the death of Bergman.

‡ Theſe laſt ſubſtances, claſſed by Bergman among the earths, belong, according to our chemical diviſion, to ſaline ſubſtances.

Species III. Aerated lime impregnated with bitumen or petroleum; ſwine-ſtone. It is found in France at Villers-Cotterets, at Plombieres, at Ingrande in Anjou, at Rattwyk in Dalecarlia, at Kineculle in Weſtrogothland, at Kraſnaſelo in Ingermania, in Portugal, in Sweden, &c. It emits a fetid ſmell, when it is rubbed or heated; ſometimes the odour reſembles that of the urine of cats; and for this reaſon it has been called *lapis felinus* by ſome authors. With acids it effervefces; in the fire it decrepitates, and loſes its odour and colour. When diſtilled in large quantities, it affords, 1. A fetid liquor, which reddens ſyrup of violets, and effervefces with acids. 2. A black ſtrong ſmelling oil, reſembling that of pit-coal. 3. Concrete volatile alkali. The reſidue contains a little marine ſalt. This ſubſtance owes its diſtinguiſhing properties to the bitumen it contains.

Species IV. Fluorated lime. Fluor mineral, or vitreous ſpar, combination of lime, with the ſparry or fluor acid mixed with clay, ſiliceous earth, or a ſmall quantity of marine acid.

Species V. Lime ſaturated with a peculiar acid, probably metallic *. Heavy ſtone, tungſten of the Swedes. This is the heavieſt of all ſtones. It is found in ſmall yellow or red grains, in the mines of Baſtnas, near Ritterhutte in Weſtmanland; and alſo of a ſpathoſe, brilliant, and whitiſh appearance at Marienburgh, and at Altenburg in Saxony. It is often compounded with the white tin ore. It reſiſts the fire, and only vitrifies at the ſurface. It is not ſoluble in boiling water. The vitriolic acid ſeizes the lime. The nitrous acid, being added to a ſolution of this ſtone in volatile alkali, precipitates a white powder, which is the peculiar acid diſcovered by Scheele *. The tungſten may be diſtinguiſhed from every other ſtone by pouring the nitrous or marine acid upon it in powder, which laſt becomes of a beautiful yellow on being ſlightly heated. (See the *Journal de Phyſique*, 1783, Vol. XXII.)

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* Since found to be ſo. See *Scheele's Eſſays*, and *De Luyarts on Wolfram*, both tranſlated into Engliſh, and publiſhed in London. T.

Species VI. Aerated lime contaminated † with a ſmall quantity of muriatic magneſia, or marine ſalt of magneſia.

Species VII. Aerated lime contaminated with clay. Falſe marl.

Species VIII. Aerated lime, contaminated with ſiliceous earth. Some calcareous ſtones uſed by maſons, and certain marbles, are obſerved to give fire with the ſteel, by reaſon of the fragments of ſilex or quartz they contain.

Species IX. Aerated lime, contaminated with argillaceous and ſiliceous earths. Perfect marl.

Species X. Aerated lime, contaminated with iron and magneſia; falſe white iron ore; pulverulent and black, or hard and red, or whitiſh. The mines of Halleſors afford theſe varieties.

Magneſia.

Species I. Pure magneſia; always produced by art.

Species II. Aerated magneſia; found diſſolved in waters impregnated with aerial acid.

Species III. Aerated magneſia, mixed with ſiliceous earth. It is ſcintillant and efferveſcent.

Species IV. Magneſia intimately combined with ſiliceous earth and clay; ſteatites, Briançon chalk, ſoap ſtone, lapis ollaris, ſerpentine, lapis nephriticus.

Species V. Magneſia united to a conſiderable portion of ſiliceous earth with a ſmaller quantity of calcareous and argillaceous earths, and contaminated by calx of iron. Aſbeſtos; mountain cork; mountain leather; amianthus. Bergman found in a centenary of amianthus, 64 parts of ſiliceous earth, 18.6 of magneſia, 6.9 of

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[*] De Luyarts have ſhown that this is a triple ſalt, conſiſting of wolfram-calx, volatile alkali, and nitrous acid. It is ſoluble in water, and has acid properties. The pure calx, though not evidently ſoluble in water, reſembles acids in its affinities with alkali and lime, and its inſolubility in acids. T.

[†] The word *contaminated* (*inquinatus*) is uſed by Bergman to denote a ſimple mixture of two or more earths, without a true combination. We have therefore ſubſtituted occaſionally the word *mixed* in its place. Note of the Author.

lime, 6 of vitriolated ponderous earth, 3.3 of clay, and 1.2 of calx of iron: and the ſame quantity of aſbeſtos afforded 67 parts ſilex, 16.8 of magneſia, 6 of clay, 6 of lime, and 4.2 of calx of iron.

Species VI. Magneſia mixed with argillaceous and ſiliceous earths and pyrites; a ſpecies of alum ore deſcribed and analyſed by M. Monnet (*Syſt. de Minéralogie*, Genre 9. pag. 161.)

Species VII. Magneſia mixed with argillaceous and ſiliceous earths, together with petroleum and pyrites; magneſian aluminous ſchiſtus.

Clay.

Species I. Pure clay; it is precipitated from alum by the aerated volatile alkali.

Species II. Clay mixed with ſiliceous earth. Porcelain clay, kaolin of the Chineſe. Solid clay of Saint-Iriez in Limouſin, of Japan, and of Saxony. Pulverulent clay of Weſtmanland, of Boſerup, and of China. Theſe earths are often mixed with mica. The clays uſed in the more ordinary kinds of pottery are coarſer, but of the ſame nature.

Species III. Clay mixed with ſiliceous earth and iron. Boles, or bolar earths, grey, yellow, red, brown, or black. They are waſhed, in order to make the ſealed earths. The common clays of a green, blue, and red colour, are of this ſpecies.

Species IV. Clay mixed with ſiliceous and calcareous earth. Argillaceous marl; tobacco-pipe clay; agaric mineral or foſſil.

Species V. Clay mixed with ſiliceous and magneſian earth. Lemnian earth; fuller's earth; ſoap rock; ſmectites. Bergman has obtained from the Lemnian earth, the Hampſhire clay, and the fuller's earth of England, a large portion of ſiliceous earth, about 1-5th of clay and aerated lime, and 1-20th of aerated magneſia and calx of iron. He gives the generic name of lithomarga to theſe earths.

Species VI. Clay contaminated with ſulphur and vegetable alkali. Alum ore of Tolfa and Solfatara. Bergman conſiders it as a volcanic product.

Species VII. Clay mixed with ſiliceous earth, pyrites, and petroleum. Aluminous ſchiſtus. It is found in Italy, in the province of Liege, in Sweden, and in Jemtland. The black crayons, ſuch as thoſe from Bechel near Seez in Normandy, and the ampelites, are of this ſpecies. The tripolis are an aluminous ſchiſtus more or leſs burnt. Such are thoſe of Poligné in Normandy, and of Menat in Auvergne.

M. Mongez reckons in this ſpecies the ſchiſti, which contain clay in a large proportion, and more or leſs of ſiliceous earth and bitumen. The greater number are mixed with calcareous earth, and effervefce with acids. The proportions of theſe principles vary greatly in the different ſchiſti. There are ſome of ſo bituminous a nature, that they burn with a flame; others are loaded with pyrites, and effervefce in the air; and others are very hard, and give fire with the ſteel. M. Mongez admits five varieties. 1. The hard argillaceous ſchiſtus, or writing ſlate. 2. The ſoft argillaceous ſchiſtus, or roof ſlate. 3. The ſoft ſiliceous ſchiſtus, or poliſhing ſtone for metals. 4. The hard ſiliceous ſchiſtus, or ſtone for ſetting razors. 5. The hard calcareous ſchiſtus, which makes a bad lime; as that of Allevard in Dauphiny.

Species VIII. Clay combined with leſs than half its weight of ſiliceous earth, a ſmall portion of aerated lime and calx of iron; cryſtal gems. The happy reſearches of Bergman into the nature of gems, whoſe exceſſive hardneſs and immutability ſeem to defend them from the operations neceſſary to their chemical analyſis, have been confirmed by the labours of Margraaf, Gerhard, and Achard. Here follow the reſults of Bergman's analyſis of five Cryſtal gems, which are varieties of the ſpecies we are now attending to:

	Clay.	*Silex.*	*Lime.*	*Iron.*
Oriental emerald contains -	60	24	8	6
Oriental ſapphire - -	58	35	5	2
Saxon topaz - -	46	39	8	6
Oriental hyacinth - -	40	25	20	13
Oriental ruby - -	40	39	9	10

The methods which this celebrated chemiſt has put in practice, in order to obtain a knowledge of the component principles of theſe ſtones, are very ingenious, and at the ſame time very ſimple. (See *Bergman's Eſſays*, in Engliſh, London, 1784.)

Species IX. Clay combined with ſiliceous earth, compoſing more than half of the total weight, with a very ſmall quantity of aerated lime and iron, garnet; ſchorl; tourmalin. The proportion of iron varies in theſe ſtones. (See the *Analyſis of the Tourmalin of Tyrol*, by M. Muller; *Journal de Phyſique*, Vol. XV. p. 182, ann. 1780.)

Species X. Clay ſlightly united with ſiliceous earth, compoſing the half of the weight, and ſometimes more, together with a ſmall proportion of lime; zeolite. M. Mongez conſiders the azure ſtone, lapis lazuli, as a zeolite. M. Margraaf has found a ſmall quantity of gypſum ready formed in the lapis lazuli.

Species XI. Clay united to much ſiliceous earth, and a little magneſia; talc; mica. The proportion of the principles which compoſe this ſtone have not been exactly aſcertained.

Siliceous Earth.

Species I. Pure ſiliceous earth. It is prepared by fuſing clear quartz with four parts of fixed alkali, diſſolving the whole in diſtilled water, and precipitating the earth by an acid. This earth is to be well waſhed and dried.

Species II. Siliceous earth united to a very ſmall proportion of calcareous and argillaceous earth. Rock cryſtal, with its varieties; quartz and its varieties; grit-ſtone and its varieties.

Species III. Siliceous earth united with argillaceous earth. Chalcedony hydrophanes, or oculus mundi; this contains more clay than ſiliceous earth, according to M. Gerhard of Berlin. Opal; M. Mongez conſiders, as varieties of this ſtone, the cat's eye, the fiſh's eye, and the giraſol: To theſe three ſorts of ſtones he adds the agate, and its varieties; the cacholong, the cornelian, the ſardonyx, the gun-flint, the jade. Their analyſis has not yet been made with much exactneſs.

Species IV. Siliceous earth united to a very martial clay; jaſper. M. Mongez reckons the ſinople as a variety of jaſper.

Species V. Siliceous earth rendered heavy by martial earth. Falſe jaſper. M. Mongez calls this ſtone metallic quartz. He diſtinguiſhes it into the black-coloured by iron, and the red-coloured by copper.

Species VI. Siliceous earth united to argillaceous earth, and a ſmall portion of lime; petroſilex. This ſtone ſometimes gives ſparks with the ſteel, and efferveſces with acids; it melts in a ſtrong fire.

Species VII. Siliceous earth united to clay, and a ſmall portion of magneſia; feld-ſpar. It changes colour in the fire, and melts. It does not become decompoſed by air; it gives ſparks with the ſteel, and breaks eaſily.

Species VIII. Siliceous earth united to magneſia, aerated and fluorated lime, with the calces of iron and of copper. Praſe, chryſopraſe. It is from the analyſis of M. Achard, that Bergman deſcribes the compoſition of this ſtone.

I. APPENDIX.

Bergman, in his firſt appendix, treats of minerals united, or mechanically mixed with each other, in ſuch a manner, as that the parts may be diſtinguiſhed by the eye. We ſhall here mention only the mixtures of earths. Such are the ſtones called rocks, ſaxa. M. Mongez, who has added much to the labours of Bergman on this ſubject, diſtinguiſhes theſe ſtones or rocks into two genera. 1. Such as have not their parts united by means of any cement, but adhering ſimply by juxtapoſition, being formed by various fragments agglutinated together. He diſtinguiſhes them into three ſpecies; granite, gneis of Saxony, and horn-ſtone. 2. The mixed ſtones, whoſe parts are encruſted in a common cement; as is the caſe in four kinds; namely, porphyry, ophites or ſerpentine, breccias and pudding-ſtone. We ſhall, in this place, exhibit the varieties of theſe ſtones admitted by this naturaliſt.

I. Granite. It is formed of quartz, feld-ſpar, mica, ſchorl, and ſteatites, mixed in different proportions, two and two, three and three, or four and four; the quartz always conſtitutes the baſe.

Variety I. Granite of two ſubſtances; granitin.

A. Quartz and feld-ſpar.
B. Quartz and ſchorl.
C. Quartz and mica.
D. Quartz and ſteatites.

Variety II. Granite of three ſubſtances.

A. Quartz, feld-ſpar, and mica. It is the moſt common, the moſt abundant, and the moſt varied of any.
B. Quartz, mica, and ſchorl.
C. Quartz, ſchorl, and ſteatites.

Variety III. Granite of four ſubſtances.

A. Quartz, feld-ſpar, ſchorl, and mica.
B. Quartz, feld-ſpar, ſchorl, and ſteatites.

II. Gneis. Gneis is a mixture of quartz in grains, and mica in greater or leſs abundance, with much clay, or ſteatites, which conſtitutes the baſe. This ſtone is foliated like ſchiſtus. It is ſubject to alteration and decompoſition in the air, in conſequence of the humidity which the clay abſorbs. The Alps in Dauphiny contain many varieties of gneis.

III. Horn-stone. This ſtone is compoſed of very minute parts, among which brilliant ſpecks of mica may be diſtinguiſhed. It has an earthy aſpect; and, when moiſtened, has an argillaceous ſmell. In the fire it hardens like clays; and melts into a blackiſh ſcoria, or black glaſs, if the heat be intenſe. Its colours are various. M. Mongez conſiders the trap of the Swedes as a variety of the horn-ſtone.

IV. Porphyry ſeems to conſiſt of a hard and fine paſte, of the nature of red jaſper, which envelopes grains, either cryſtalline or irregularly ſhaped, of quartz, of white or reddiſh feld-ſpar, and ſometimes green or black ſchorl.

V. Ophites. The ophites, or hard ſerpentine, is a ſpecies of porphyry, whoſe cement is green, and the ſpots of a greeniſh white. Theſe are uſually longiſh in the ophites, while they are ſquare or rhomboidal in the porphyry. The thunder-ſtone is a variety of this ſpecies.

VI. **Breccias** (from the Italian word denoting fragment). This is a mixed ſtone, of an origin greatly poſterior to the preceding. It is formed by the deſtruction of the primitive mountains, and by irregular and worn pieces of ſilex, &c. united by one common cement. M. Mongez confounds the puddingſtones with the breccias. He gives a compound name to the latter, which indicates the nature of their fragments, and the cement which unites them. He diſtinguiſhes eight varieties. The calcareous breccia, which is the breccia properly ſo called, and the lumachello; the ſiliceo-ſiliceous breccia, or the puddingſtone *; the breccia with a calcareous cement, and fragments of the calcareous and ſiliceous genus; the breccia with ſiliceous cement, and fragments of the calcareous and ſiliceous genus; the arenario-ſiliceous breccia, ſuch as the griſon of Chartres; the breccia with cement and fragments of jaſper; the breccia with cement and fragments of porphyry; and the volcanic breccia.

II. APPENDIX.

Volcanic Products.

M. Mongez divides the volcanic products, after Bergman, into ſuch as have been formed by fire, and ſuch as owe their origin to water. The latter are nothing more than ſuch earthy ſubſtances as have been diſſolved and ſuſpended in water, and afterwards depoſited in the neighbourhood, and among the products of volcanos; ſuch are the calcarcous and ſiliceous encruſtations, as well as the zeolites frequently found in volcanic productions.

M. Mongez divides the true volcanic products into three orders. 1. Earthy ſubſtances very little changed by the fire; as calcareous matters, clays, garnets, hyacinths, ſchorls, and mica. 2. Earthy ſubſtances calcined and burned; as the volcanic aſhes, or the rapillo and puzzolana, the tufa, the peperino of the Italians, the pumice ſtone, and the white earth which covers the ſolfatara. 3. Earthy ſubſtances melted, or lavas, of which he admits ſeveral ſpecies; ſpongy, compact, and ſtalactitical lavas, and volcanic glaſs. To theſe diviſions he adds the earthy volcanic products of uncertain origin. In this order he particularly ranks the garnets, the volcanic ſchorl, and eſpecially the baſaltes, which he thinks are maſſes of trap ſoftened by the humid vapours of volcanos, and afterwards ſlowly dried when the vapours have ceaſed.

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* According to this nomenclature, the firſt word expreſſes the nature of its cement, and the ſecond that of its fragments. Note of the Author.

§ 3. *Claſſification of Earths and Stones by Mr. Kirwan.*

Mr. Kirwan, a celebrated chemiſt of Dublin, publiſhed, in 1795, a ſecond edition of his Elements of Mineralogy. In this edition, which is greatly enlarged and improved, Mr. Kirwan has adopted the method of the Wernerian ſchool, and has given a claſſification of minerals founded on the union of their external with their internal characters.

The external characters he enumerates are colour, ſhape, luſtre, tranſparency, texture, coheſion, denſity, adheſion to the tongue and fingers, and general feel, colour of a ſtreak, abſorption or diffuſion in water, ſmell, and taſte.

The internal characters are, relation to acids, changes operated in low heats, fuſibility, and other changes in higher degrees of heat, phoſphoreſcence, magnetiſm, electricity, and laſtly, the reſults of a juſt analyſis. The earths and ſtones are ranked in his firſt part. After having given as the characters of theſe ſubſtances, inſipidity, dryneſs, brittleneſs, incombuſtibility, and inſolubility in leſs than one thouſand times their weight of water, he admits nine genera of ſimple earths; the calcareous; the barytic; the magneſian, or muriatic; the argillaceous; the ſiliceous; the Scottiſh, or Stronthian; the jargonic; the Sydneian, and adamantine. Under theſe genera he places all the known earths and ſtones.

CALCAREOUS GENUS.

UNDER THIS HEAD IS COMPREHENDED ALL THOSE EARTHS AND STONES, APPARENTLY HOMOGENEOUS, IN WHICH CALCAREOUS EARTH PREDOMINATES.

SPECIES I. Native Lime.

SPECIES II. Carbonate de Chaux,

Combined with fixed air, aerated or mild calx.

Class I. *Mild calx in a looſe or ſemi-indurated form.*

Family I. Agaric mineral, bergmilch or bergmehl of the Germans.

Family II. Chalk.

Family III. Arenaceous limeſtone. Ganil.

Family IV. Teſtaceous tufa.

Class II. *Indurated.*

Family I. Compact limeſtone.

Family II. Foliated and granular.

Family III. Foliated and ſparry. Spars.

Family IV. Striated or fibrous. Stalactite, alabaſter, ſinter.

Family V. Swine ſtone.

Family VII. Oviform. Erleſenſtein.

SPECIES III. Baryto-Calcite.

Mild calcareous earth, mixed with a notable proportion of other earths, iron, or manganeſe. Mixed with barytes or baroſelenite.

SPECIES IV. Muricalcite.

Mixed with magneſia.

Family I. In an earthy form.

Family II. In a ſtony form, and amorphous.

Family III. Cryſtallized. Compound ſpar. Bitter ſpar of the Germans.

SPECIES V. Argillo-calcites.

Mixed with a notable proportion of argill or clay.

Class I. Marls, or Calcareous Marls, *readily diſintegrable by expoſure to the atmoſphere.*

Family I. In an earthy or ſemi-indurated form. Mergelerde of Werner.

Family II. In a ſtony or indurated ſtate. Verharteter mergel of Werner.

Branches. { 1. Argillaceous.
2. Siliciferous marls.

CLASS II. Marlites, *not readily diſintegrable by expoſure to the atmoſphere.*

Family I. In which, next after the calcareous ingredient, the argillaceous predominates. Argilliferous marlites.

Family II. In which, next to calx, ſilex predominates. Siliciferous marlites.

Of this there are many varieties; ſeveral of which give fire with ſteel, at the ſame time that they efferveſce with acids.

CLASS III. Argillocalcites, *penetrated with bitumen, ſulphur, or pyrites.*

Family I. Bituminous marlite. Bituminoſer mergel ſchiefer of Werner.

Family II. Pyritaceous limeſtone.

SPECIES VI. Argentine.

Schiefer ſpath of Werner.

SPECIES VII. Sidero Calcite.

Braun ſpath of Werner, Spath perlé of Romé de Liſle.

Combined with mangancſe and iron.

SPECIES VIII. Ferricalcites.

Mixed with a notable proportion of iron.

SPECIES IX. Dolomite.

Superſaturated with fixed air, and frequently phoſphoreſcent.

Family I. Common dolomite. Dolomie of Sauſſure.

Family II. Elaſtic marble.

SPECIES X. Gypſum. Selenite.

Combined with the vitriolic acid.

Family I. Farinaceous gypſum.

Family II. Compact gypſum. Dichter gypſtein of Werner. Alabaſter.

Family III. Fibrous, or ſtriated.

Family IV. Foliated.

Varieties.
- 1. Granularly foliated. Blattriger gypſtein of Werner.
- 2. Broad foliated. Specular gypſum. Fraueneis of Werner. Glacies Mariæ.

SPECIES XI. Fluor.

Flus of Werner.

Combined with the ſparry acid.

Family I. In a ſandy or earthy form.

Family II. Compact.

Family III. Foliated, or ſparry. Fluor ſpar.

SPECIES XII. Phoſpholite.

Combined with the phoſphoric acid.

Family I. Phoſphorite. Apatite of Werner.

SPECIES XIII. Tungſten.

Combined with the tungſtenic acid.

Varieties.
- 1. Grey tungſten. Scheelium of Werner, white zin-graupen of many.
- 2. Brown tungſten. Goſſan of the Corniſh miners.

BARYTIC GENUS.

SPECIES I. Barolite, or aerated barytes.

Witherite of Werner.

SPECIES II. Baroſelenite.

Barytes combined with the vitriolic acid.

Family I. In an earthy looſe form.

Family II. Compact baroſelenite. Dichter ſchwer ſpath of Werner.

Family III. Foliated.

Family IV. Striated, or fibrous.

Family V. Acicular. Stangen ſpath of Werner.

SPECIES III. Liverſtone.

Lapis hepaticus, leberſtein.

MURIATIC GENUS.

UNDER THIS HEAD MR. KIRWAN INCLUDES NOT ONLY THOSE EARTHS AND STONES IN WHICH MAGNESIA PREDOMINATES, BUT ALSO THOSE IN WHICH THE SILICEOUS EARTH PREDOMINATES, IF MAGNESIA BE, NEXT AFTER THIS, THE MOST COPIOUS INGREDIENT, AND THE COMPOUND POSSESSES THE CHARACTERS OF THE MURIATIC, AND NOT THOSE OF THE SILICEOUS GENUS.

SPECIES I. Silicimurite.

Magneſia mixed with ſilex.

Family I. Keffekill. Myrſen. Meerſchaum of Werner.

Family II. Martial muriatic ſpar.

SPECIES II. Calcimurite.

Magneſia mixed with a notable proportion of calcareous earth and ſome iron.

SPECIES III. Argillo-Murite.

Mild magneſia mixed with clay and iron.

SPECIES IV. Chlorite.

Samt erde. Peach of the Corniſh miners.

Family I. In a looſe form.

Family II. Indurated and cryſtallized.

Family III. Slaty.

SPECIES V. Talc.

Family I. In a looſe or ſemi-indurated form. Talcite.

Family II. Talc. Or common talc. Venetian talc.

Family III. Schiſtoſe talc. Schiefriges talc.

SPECIES VI. Steatites.

Family I. Semi-indurated. Craie de Briançon. Specſtein of Werner.

Family II. Indurated ſteatites. Lardites of Wallerius. Schmeerſtein of Succow.

Family III. Foliated, or ſtriated. Talcites of Wallerius.

SPECIES VII. Pot-Stone.

Lapis ollaris. Verharteter talc, or topfſtein of Werner.

SPECIES VIII. Serpentine.

SPECIES IX. Aſbeſtos.

Aſbeſte non mur of the French.

SPECIES X. Ligniform Aſbeſtos.

SPECIES XI. Amianthus.

SPECIES XII. Suber Montanum.

Corium montanum.

SPECIES XIII. Amianthinite.
Aſbeſtartiger ſtrahlſtein of Werner, in part.

SPECIES XIV. Aſbeſtinite.
Gemeiner ſtrahlſtein of Werner.

SPECIES XV. Abeſtoid.
Of this I diſtinguiſh two families.

Family I. Common aſbeſtoid. Gemeiner ſtrahlſtein of Werner.
Family II. Metalliform aſbeſtoid. Aſbeſtartiger ſtrahlſtein of Werner, in part.

SPECIES XVI. Lamellar Actynolite.
Aſbeſtartiger ſtrahlſtein of Werner.

SPECIES XVII. Schorlaceous Actynolite.
Gemeiner ſtrahlſtein of Werner, in part.

SPECIES XVIII. Glaſſy Actynolyte.
Glaſſartiger ſtrachlſtein of Werner.

SPECIES XIX. Jade.
Nephrit of Werner. Bitterſtein of Hoepfner, and others.

SPECIES XX. Boracite.
Combined with the boraccic acid, and boracited calx.

SPECIES XXI. Baikalite.

ARGILLACEOUS GENUS.

CLASS I. Argillaceous Earths. *Theſe are for the moſt part diffuſible in water, and do not immediately ſink in* *it as ſands do; or if ſo compact as immediately to ſink, they ſoften, crumble, or moulder away in it, ſome ſooner, ſome later, either to a ductile viſcid pulp, or to a powder.*

TRIBE I. Native Argill.

Lac lunæ of ſome. Reinethon erde of Werner.

TRIBE II. Porcelain Clay. Kaolin

TRIBE III. Common Clays,

In various ſtates of induration.

Family I. Potters clay.

Family II. Indurated clay. Verharteter thon of Werner.

Family III. Schiſtoſe clay.

Varieties. { 1. Slate clay, Shale. Schiefer thon of Werner.
2. Bituminous ſhale. Brandſhiefer of Werner.

Family IV. Fullers earth. Walkererde of the Germans, Smectis.

TRIBE IV.

The finer clays in various ſtates of induration.

Family I. Lithomarga. Steinmarck of the Germans.

Theſe earths are principally diſtinguiſhed by their great fineneſs, and fuſibility into a frothy ſlag.

Varieties. { 1. The friable or crumbling kind.
2. Indurated lithomarga.

Family II. Bole.

TRIBE IV. Argillaceous Marls.

TRIBE V. Colorific Earths,

Or thoſe which ſtrongly ſtain the fingers.

Family I. Red. Reddle. Rubrica fabrilis.

Family II. Yellow. Gelbe erde.

Family III. Black. Black chalk. Schwartze Kreide, Zeichen Schiefer. Pierre noir of Briſſon.

Family IV. Green earth.

Umber.

TRIBE VI. Harſh and Rough Earths.

Of theſe are two families; tripoli, and puzzolana, or terras.

Family I. Tripoli.

Family II. Puzzolana, or terras.

Of this I ſhall treat under the head of Volcanic Products.

Struvian Clay.

CLASS II. *Stony ſubſtances of the Argillaceous Genus not mouldering in water.*

SPECIES I.

Argill combined with vitriolic acid or ſulphur.

This forms ores of alum.

SPECIES II. Phoſphorite,

Argill combined with the phoſphoric acid.

SPECIES III. Lepidolite.

Lilalite of ſome.

SPECIES IV. Sappare.

Cyanite of Werner.

SPECIES V. Mica, Muſcovy Talc,

Glimmer of the Germans.

SPECIES VI. Micarelle,

SPECIES VII. Hornblende.

Pierre de corne of the French. Schorl en maſſe, and ſchorl ſpathique of Briſſon.

SPECIES VIII. Baſaltine.

Baſaltic hornblende, or Cryſtallized hornblende, of Werner. Schorl ſpath of Ferber. Schorl priſmatique hexagone of Sauſſure.

SPECIES IX. Reſplendent Hornblende.

Of this there are two varieties.

Varieties. {
1. Labradore hornblende.
2. Schiller ſpar.

SPECIES X. Schiſtoſe Hornblende.

Hornblende ſlate. Hornblende ſchiefer of Werner. Roche de corne feuilletées. 1 Sauſſ. § 166. p. 119.

SPECIES XI. Wacken.

SPECIES XII. Mullen Stone.

SPECIES XIII. Kragg Stone.

SPECIES XIV. Trap.

Family I. Amorphous. Common trap. Baſalt of Werner.
Family II. Figurate trap, Baſalt. Baſalt of Werner.

SPECIES XV. Calp,

Or black quarry ſtone of Dublin.

SPECIES XVI. Argillite,

Or argillaceous ſchiſtus or ſlate. Thon ſchiefer of Werner.

SPECIES XVII. Novaculite.

Turkey hone. Schiſtus coticularis of Wallerius. Pierre raſoir. Wetzſtein of Werner.

SILICEOUS GENUS.

SPECIES I. Mountain Cryſtal and Quartz.

Theſe form two families, the only difference being in their fracture and tranſparency.

Family I. Mountain or rock cryſtal.
Family II. Quartz.

SPECIES II. Amethyſt.

SPECIES III. Emerald.

SPECIES IV. Beryl.

Aigue marine of many.

SPECIES V. Praſium.

SPECIES VI.

Family I. Oriental ruby.
Family II. Oriental topaz.
Family III. Oriental ſapphire.

SPECIES VII. Spinell and Balaſs Rubies.

SPECIES VIII.

Family I. Occidental or Brazilian ruby.
Family II. Occidental topaz.

Varieties.
- 1. Brazilian.
- 2. Saxon.
- 3. Topaz.

Family III. Occidental or Brazilian ſapphire.

SPECIES IX. Hyacinth.

SPECIES X. Garnet.

Varieties.
- 1. Oriental garnet. Carbuncle.
- 2. Common garnet.
- 3. Amorphous garnet.

SPECIES XI. Chryſoberyl.

SPECIES XII. Chryſolite.

SPECIES XIII. Olivin.

SPECIES XIV. Obſidian.

SPECIES XV. Schorl.

Schwartzer ſtangen ſchorl of Werner.

SPECIES XVI. Tourmaline.

SPECIES XVII. Thumerſtone.

Schorl violet de Dauphiné. Glaſs ſchorl of ſome.

SPECIES XVIII. Prehnite.

SPECIES XIX. Ædelite,

Or ſiliceous zeolite.

SPECIES XX. Zeolite.

SPECIES XXI. Staurolite,

Or croſs ſtone of St. Andreaſberg, in the Hartz. Kreutz cryſtal of the Germans. Hyacinth blanche of 2 Romé, p. 299.

SPECIES XXII. Lapis Lazuli.

SPECIES XXIII. Chryſopraſium.

SPECIES XXIV. Veſuvian,

Or white garnet of Veſuvius. Leucit. Werner,

SPECIES XXV. Schorlite.

Schorlartiger beryl of Werner. Stangenſtein of Leſke.

SPECIES XXVI. Rubellite,

Red ſchorl of Siberia.

SPECIES XXVII.

Of this there are four families; opal, ſemi-opal, pitchſtone, or pechſtein, and ligniform.

Family I. Opal edler, gelber opal of Werner.
Family II. Semi-opal.
Family III. Pitchſtone.
Family IV. Ligniform opal or pitchſtone.

OF HYDROPHANES.

Such opake ſtones as become tranſparent by placing them in water, are called *Hydrophanes.*

SPECIES XXVIII. Hyalite,

Muller's glaſs of the Germans. Lava glaſs of many,

SPECIES XXIX. Calcedony.

Family I. Calcedony, or common calcedony.
Family II. Carnelian.

SPECIES XXX. Cat's Eye,

SPECIES XXXI. Flint,

Feuerſtein of the Germans.

SPECIES XXXII. Hornſtone.

Family I. Hornſtein of the Germans, petroſilex, chert.

Family II. Schiſtoſe hornſtone. Schiefriges hornſtein. Voight Abhand, p. 81.

Varieties.
- 1. Siliceous ſchiſtus, gemeiner kieſel ſchiefer of Werner.
- 2. Baſanite. Lydian ſtone of Werner. Black jaſper of ſome.
- 3. Hornſlate of Charpentier and Voight. Schiſtoſe porphyry of Werner.

SPECIES XXXIII. Jaſper.

Family I. Common jaſper.

Family II. Egyptian pebble.

Family III. Striped jaſper. Band jaſper of Werner.

Family IV. Sinople.

SPECIES XXXIV. Porcellanite,

Porcelain jaſper of Werner.

SPECIES XXXV. Heliotropium.

SPECIES XXXVI. Woodſtone.

Holzſtein of Werner. Lithoxylon of others.

SPECIES XXXVII. Elaſtic Quartz.

SPECIES XXXVIII. Feld-Spar.

Family I. Common feld-ſpar, or feld-ſpar ſimply ſo called. Spath fuſible of Deſmaretz, ſpath etinulant, ſpathum pyromachum.

Family II. Moon ſtone, adulario of Pini.

Family III. Continuous feld-ſpar. Feld-ſpar en maſſe,

SPECIES XXXIX. Labradore Stone.

Labradore feld-ſpar of Werner.

SPECIES XL. Petrilite,

Or cubic feld-ſpar of Karſten.

SPECIES XLI. Felſite,

Or compact feld-ſpar of Widenman.

SPECIES XLII. Argentine Feld-Spar,

Or oculus piſcis.

SPECIES XLIII.

Redſtone of Rawenſtein, 3 Mem. Lauſan. p. 129.

SPECIES XLIV. Siliceous Spar.

Saulen ſpath of Bindheim.

OF AGATES.

Agates, as Mr. Werner juſtly remarks, do not form a diſtinct ſpecies of ſtone, but conſiſt of quartz, cryſtal, hornſtone, flint, calcedony, amethyſt, jaſper, carnelian, heliotropium, jade, aggregated in binary, ternary, or more numerous combinations, and ſuſceptible of a good poliſh; even one of theſe, if it preſents two or more colours, and aſſumes a good poliſh, is called an agate. Theſe mixtures preſent either dots, veins, zones, filaments, figures of various kinds, ramifications, or arborizations.

Their colours are, the clear yellowiſh, reddiſh, milk, or greyiſh, or bluiſh white, or pearl grey, or honey, ochre, or orange *yellow*, fleſh, blood, or brick *red*, or reddiſh *brown*, violet *blue*, or browniſh *green*.

GENUS VI.

STRONTHIAN EARTH.

SPECIES I. Stronthianite.

Combined with fixed air.

GENUS VII.

JARGON. Zircon of the Germans.

GENUS VIII.

SYDNEIA.

Of this no ſpecies has as yet been found; nor has it been detected in any other ſtone.

GENUS IX.

ADAMANTINE EARTH.

SPECIES I. Adamantine Spar.

This earth hath hitherto been diſcovered only in adamantine ſpar, though its exiſtence may be ſuſpected in ſome feld-ſpars.

OF AGGREGATED STONES.

Theſe conſiſt of either grains (angular maſſes) of ſtones ſimply compacted together, and forming either uniform or ſlaty maſſes; or of ſtones of one or more ſpecies, inhering in another ſtone, which may be conſidered as their baſis or cement; or of rounded ſtones of different ſorts, adhering to, or inhering in, ſome other; or of maſſes of different aggregates inhering or adhering to each other.

Granite.

This name denotes an aggregate of quartz, feld-ſpar, and mica.

Sienite.

An aggregate of quartz, hornblende, and feld-ſpar, or of quartz, feld-ſpar, hornblende, and mica.

Granatine.

Beſides the aggregates already mentioned, there are various other triple compounds, which may be denoted by the name of *Granatines*.

Quartz	Quartz	Quartz	Quartz	Quartz	Quartz
Feld-ſpar	Feld-ſpar	Feld-ſpar	Mica	Mica	Mica
Jade	Schorl	Garnets	Schorl	Jade	Garnet

Quartz	Quartz	Quartz	Quartz	Quartz	Quartz
Schorl	Schorl	Schorl	Hornblende	Hornblende	Jade
Hornblende	Jade	Garnet	Jade	Garnet	Garnet

Quartz
Hornblende
Hornſtone

Feld-ſpar	Feld-ſpar	Feld-ſpar	Feld-ſpar
Mica	Mica	Quartz	Quartz
Schorl	Hornblende	Serpentine	Steatites.

OF BINARY AGGREGATES OF THE GRANITIC KIND.

Granitell.

Binary aggregates of quartz, feld-ſpar, mica, ſchorl, hornblende, &c.

The granitells hitherto noticed by Sauſſure, Hœpfner, and Haidinger, are,

Quartz	Quartz	Quartz	Quartz	Quartz	Quartz	Quartz
Feld-ſpar	Mica	Schorl	Hornblende	Jade	Garnet	Steatites.

Feld-ſpar	Feld-ſpar	Feld-ſpar	Feld-ſpar	Feld-ſpar
Mica	Schorl	Hornblende	Jade	Garnet

Mica	Mica	Mica	Mica
Schorl	Hornblende	Jade	Garnet

Hornblende	Hornblende
Jade	Garnet

Jade	Indurated Steatites
Garnet	Schorl. 1 Sauſſ. 104.

Grunſten,

Compoſed of hornblende, feld-ſpar, or mica.

Granilite.

Granites indeterminatus of Hœpfner.

Under this denomination are comprehended all granites that contain more than three conſtituent parts.

Quartz	Quartz	Quartz	Quartz	Quartz	Quartz
Feld-ſpar	Feld-ſpar	Mica	Feld-ſpar	Baroſelenite	Baroſelenite
Mica	Mica	Schorl	Mica	Mica	Mica
Schorl	Steatites	Garnet	Garnet	Schorl	Hornblende.

Gneis.

Roche feuilletée of Sauſſure.

This conſiſts of quartz, feld-ſpar, and mica. Of *a thick, ſlaty, continuous, or fibrous texture,* and not of a granular, as when they form granite. And hence a ſlaty granite is not on that account to be called a gneis, as it is ſtill granular.

Schiſtoſe Mica.

Glimmer ſchiefer of Werner. Roche feuilletée of Sauſſure.

Porphyry.

Any ſtone which, in a *ſiliceous* or *argillaceous* ground or baſis, contains ſcattered ſpecks, grains, or dots of feld-ſpar, viſible to the naked eye, is denominated a *porphyry.*

OF SILICEOUS PORPHYRIES.

Siliceous porphyries have either jaſper, hornſtone, pitchſtone, obſidian, ſiliceous ſchiſtus, ſchiſtoſe hornſtone, or feld-ſpar itſelf for their baſis.

Jaſper Porphyry.

The exiſtence of this has lately been called in queſtion.

Hornſtone Porphyry.

Pitchſtone Porphyry.

Obſidian Porphyry.

Horn Porphyry. Porphyry ſchiefer of Werner.

Petunſe Porphyry.

Porphyry that has feld-ſpar for its baſis is called by this name.

OF ARGILLACEOUS PORPHYRIES.

Theſe may have indurated clay, hornblende, trap, wacken, mullen, kragg, or argillite, for their baſis.

Clay Porphyry.

Hornblende Porphyry. Ophites of Briſſon.

Trap Porphyry.

Wacken Porphyry.

Mullen Porphyry.

Kragg Porphyry.

Argillitic Porphyry.

Novaculite Porphyry.

Muriatic Porphyries.

Theſe have either potſtone or ſerpentine for their baſis.

Potſtone Porphyry.

Serpentine Porphyry.

Granitic Porphyry.

Sandſtone Porphyry.

Amygdaloid. Mandelſtein of Werner.

By this name Mr. Kirwan underſtands any ſtone, of the argillaceous claſs, which contains as in a ground, or baſis, rounded or elliptic maſſes of calcedony, agate, zeolite, calcareous ſpar, lithomarga, ſteatites, green earth, often alſo garnets, hornblendes, and opal; with ſome or other of theſe, though very rarely, feld-ſpar has alſo been found.

This baſis is generally indurated clay, trap, wacken, mullen, kragg.

Pudding-ſtone.

A collection of rounded pebbles, of the ſiliceous genus, cemented by a ſubſtance of the ſame genus, or a ferruginous compound of equal hardneſs.

Sandſtones.

Theſe conſiſt of grains, not exceeding 1-3d of an inch, of quartz, flint, hornſtone, ſiliceous ſchiſtus, feld-ſpar, or ſometimes mica imbedded in a calcareous, argillaceous, ſiliceous, or ferruginous cement; the ferruginous is, indeed, very frequently intermixed alſo with the foregoing.

Calcareous Sandſtones.

Argillaceous Sandſtones.

Siliceous Sandſtones.

Ferruginous Sandſtones.

Rubble Stone. Grauwacke of Werner. Gres Gris of the French.

Breccias.

Theſe are either ſimple or compound: *Simple breccias* conſiſt of angular fragments of ſtones of the ſame genus, agglutinated or compacted together; or of ſtones of one ſpecies imbedded in a cement of the ſame genus, whether the ſpecies be different or not.

Compound breccias conſiſt of fragments of ſtones, or aggregates of various ſpecies, or genera, ſtuck in a cement of a different genus; thus trap, in which fragments of granite are ſtuck, or a trap in which granite, argillaceous ſchiſtus, and limeſtone fragments, are found, form breccias.

Still many aggregates are daily met with, which cannot be arranged under any general denomination now in uſe. Mr. Kirwan propoſes to call them, if any of their conſtituent parts can be conſidered as a baſis or cement, *Porphyroids*; if none can be conſidered as a baſis, *Granitoids*.

MIXED EARTHS, AND DERIVATIVE STONES.

Earths, reſulting from the union of earths, or ſands, Mr. Kirwan calls *mixed*.

Stones, reſulting from the coalition of ſtones of different ſpecies, are called *derivatives*; they differ from *aggregates* in this, that the aſſociated ingredients are not viſibly diſtinct, or, at leaſt, require microſcopes to render them ſo.

Derivative ſtones are *limeſtones*, intimately mixed, not only with ſiliceous particles, and calces of iron, but alſo with argillite in various marbles.

Spars, contaminated with metallic ſubſtances.

Marls, diſguiſed by iron.

Gypſum, penetrated with marl, calcareous ſpar, ſwineſtone, and ſandſtone.

OF THE MURIATIC GENUS.

Potſtone, intermixed with quartz, mica, or ſome other ſtone of the ſiliceous genus.

OF THE ARGILLACEOUS GENUS.

Trap, blended, or intimately mixed with hornblende ſlate, wacken, mullen, or kragg.

Talcoſe Argillite.

Calciferous Argillite.

Hornblende Slate, penetrated with talc or mica.

Hornblende, penetrated with garnets.

Hornblende Slate, penetrated with an exceſs of quartz.

Mullen, penetrated with aſbeſtinite.

Trap, paſſing into granite.

Ferruginous Argillite.

Argillite, with an exceſs of argill.

OF THE SILICEOUS GENUS.

Iron ſhot Quartz.

Earthy Quartz.

Earthy Quartz, penetrated with yellowiſh green actinolite.

Earthy Hornſtone.

Ferruginous Hornſtone.

Siliceous Schiſtus, penetrated with argillite.

Siliceous Schiſtus, penetrated with mullen.

Siliceous Schiſtus, penetrated with limeſtone.

Pitchſtone, penetrated with opal.

Granite, penetrated with argillite.

In a Firſt Appendix, Mr. Kirwan deſcribes the

Diamond.

In a Second Appendix,

Stones and Earths that owe their Origin to Fire.

Theſe are either volcanic or pſeudo-volcanic.

VOLCANIC PRODUCTIONS.

1. *Of Lavas in general.*

Any matter that has iſſued out of a volcano in a liquified ſtate, or that has accompanied or been enveloped in ſuch liquified matter, is in general ſtyled a *lava*.

2. *Of Vitreous Lavas.*

Vitreous lavas are formed of ſuch matters as have been expoſed to the greateſt heat, or which, from their compoſition, were moſt ſuſceptible of vitrification in a moderate heat.

3. *Of Enamels.*

Analagous to vitreous lavas, are the imperfect vitrifications called *enamels*.

4. *Of Volcanic Scoriæ.*

Theſe are compounds of iron and ſtony matter that owe their fuſion to ſulphurated iron, which is known to be much more fuſible than iron in any other ſtate.

5. *Of Volcanic Slags.*

Theſe entirely reſemble the droſs of forges; they are generally red and heavy.

Of Cellular Lava.

Of Compact Lava.

By compact lava, volcanic writers denote an earthy ſubſtance, which, after having been fuſed, but not vitrified, becomes, on cooling, compact, cloſe, and ſolid.

OF VOLCANIC ASHES, SAND, PUZZOLANA, TRASS, TUFA, AND PIPERINO.

1. *Of Volcanic Aſhes.*

2. *Of Puzzolana.*

3. *Traſs, or Terras.*

Mr. Kirwan couples this with puzzolana, on account of their ſimilarity to each other, and not becauſe he looks upon it as conſtantly, and neceſſarily, a volcanic production. On the contrary he believes it to be generally the product of pſeudo-volcanos, external fires.

4. *Tufas.*

Theſe ſeem to be a puzzolana formed by nature into a mortar.

5. *Piperino.*

This alſo ſeems a concretion of volcanic aſhes, and is ſaid to be the ſubſtance that covers Pompeia.

6. *Pumice.*

OF STONY SUBSTANCES EJECTED, UNALTERED, OR BUT SLIGHTLY INJURED.

Not only ſchorls and garnets have been ejected from volcanos unfuſed, but even calcareous and fluor ſpars, with their tranſparency unimpaired.

Granites, in different ſtates.

Porphyries.

CHAPTER IV.

CONCERNING THE CHEMICAL ANALYSIS OF EARTHS AND STONES.

NOTWITHSTANDING the great attention which for ſome years paſt has been paid to the analyſis of earths and ſtones, it muſt be confeſſed that we are ſtill very far from poſſeſſing a ſufficient number of well eſtabliſhed facts to ſerve as the baſis of a methodical diviſion of thoſe ſubſtances. It is for this reaſon that the chemical methods hitherto offered to the public are ſo different from each other; and this circumſtance rendered it neceſſary to exhibit, in the preſent work, the ſyſtems of three celebrated chemiſts, though the interval between the publication of their reſpective works is by no means conſiderable.

The principal advantage derived from the labours of our cotemporaries in their inquiries into the nature of earths and ſtones, conſiſts in the diſcovery of methods for obtaining a knowledge of their principles. The methods of analyzing theſe ſubſtances is rather complicated; for which reaſon I ſhall, in the preſent chapter, exhibit merely its outlines.

The action of fire, air, and water, might be eaſily underſtood by beginners, who have read only the firſt part of this work, in which the properties of theſe ſubſtances are explained; but the ſaline matters ſo advantageouſly employed to ſeparate and to diſcover the different conſtituent principles of earths and ſtones being wholly unknown to them, we ſhould become unintelligible, and ſhould deviate from the regularity neceſſary in the ſtudy of the phyſical ſciences, were we here to treat of the uſe of theſe ſolvents in the analyſis of ſtones. I ſhall refer the detail of the accurate chemical methods of decompoſing earthy ſubſtances by means of acids and alkalis to another part of this treatiſe, explaining here only the general principles*.

When it is propoſed to examine into the chemical nature of any earth or ſtone, it is neceſſary, firſt, carefully to obſerve its phyſical properties, ſuch as its figure, hardneſs, colour, weight, &c. The extraneous matters, which are always more or leſs abundant, muſt then be ſeparated, by picking, waſhing, or otherwiſe, in order that the ſubſtance may be had pure and unmixed. A ſtone muſt be reduced into powder before its analyſis can be proceeded upon. The action of fire is one of the firſt teſts to which earths are commonly expoſed. A few ounces of the ſubſtance under examination being put into a crucible of well baked clay, or porcelain, is heated in a good furnace, ſuch as that of Macquer, or ſtill better in the potter's or glaſſmaker's furnace. It muſt be remarked, that the argillaceous earth, which conſtitutes the caſe or principal part of the crucibles employed in this operation, very often contributes greatly to the change produced by heat in the included ſubſtance. There is not, however, any method of obviating this inconvenience, which in fact is of no great conſequence in the comparative analyſis of a conſiderable number of ſtones. For ſome years paſt chemiſts have availed themſelves of the blow-pipe in the examination of mineral ſubſtances by fire; and it is certainly of advantage to employ this method as well as the other. The mineral ſubſtances are expoſed to the flame of a lamp or candle, urged by the blow-pipe, either alone or mixed together, or with the addition of certain ſalts hereafter to be deſcribed *. The apparatus deſcribed in my *Memoires de Chimie*, which is calculated to throw a ſtream of vital air on ignited charcoal, and whoſe effects are ſo conſiderable, as to equal thoſe of the moſt powerful burning-glaſſes, may be advantageouſly uſed in this inquiry. Theſe ſmall experiments exhibit a greater or leſs degree of fuſion, or ſome other changes of form, colour, conſiſtence, &c. which are to be very accurately deſcribed. This trial by fire muſt be repeated in earthen retorts, with receivers, and likewiſe the pneumato-chemical † apparatus, in order to collect the water and aeriform fluids, which are diſengaged. The laſt mentioned products are not afforded, but by ſuch ſaline earthy ſubſtances as are conſidered by naturaliſts as ſtones; but as theſe are often mixed with true earths, it is proper to mention in this place the general method of examining them. The action of fire on ſtones ſhows whether they are vitrifiable, argillaceous, or mixed; but as moſt ſtones are of the laſt mentioned kind, and may contain ſeveral different ſubſtances, to the numbers of five or ſix, and thoſe in various proportions, it becomes neceſſary, in almoſt every inſtance, to make uſe of other methods to determine their compoſition. Theſe proceſſes conſiſt in the application of a variety of acid and alkaline ſolvents, whoſe ſucceſſive action ſeparates the conſtituent principles.

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* See the analyſis of waters at the end of the work. F.

The action of air, and of the vapour of water, on earthy ſubſtances, may likewiſe ſerve to enlarge our knowledge of their nature and principles. Some earths are not altered by theſe agents, others are divided, and by degrees changed in their form, colour, and conſiſtence: Theſe phenomena take place more eſpecially in very compounded ſtones, and ſuch as contain much iron. The lixiviation or waſhing in hot or cold water ſerves, beſides, to ſhow the preſence of ſaline matters, though very inſoluble, often contained in them.

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* See the *Eſſay on the Blow-pipe*, by Bergman, annexed to Mongez' *Manuel du Mineralogiſte*, or Cullen's *Engliſh Tranſlation of Bergman.*

† For a deſcription of this apparatus, conſult the article *Gas* in the *Dictionnaire de Chimie*, in the treatiſe on the different kinds of air, by Sigaud de la Fond, &c. &c. T.

It is by theſe different methods that modern chemiſts have ſucceeded in determining the nature and proportion of the principles which enter into a conſiderable number of earths and ſtones. I have hitherto mentioned only their moſt general uſe; but in the hiſtory of ſaline ſubſtances, all the details relative to this object will be given, which it would be obviouſly improper to introduce here *.

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* The beſt account we have in the Engliſh language of the chemical analyſis of earths and ſtones, is to be found in the firſt volume of Mr. Kirwan's *Mineralogy*. T.

PART III.

SECTION I.

SALINE SUBSTANCES.

CHAPTER I.

CONCERNING SALINE SUBSTANCES IN GENERAL, THEIR CHARACTERS, NATURE, AND THE METHOD OF CLASSING THEM.

THE number of ſaline ſubſtances is very conſiderable; and they poſſeſs peculiar characters, by which they are diſtinguiſhed from the ſubſtances before treated of in this work. Theſe characters are founded on certain properties, which, it muſt be confeſſed, are not accurately diſtinctive of their true nature: By this means the claſs of ſalts has been extended too much, the general properties being common to a great number of bodies.

Taſte and ſolubility in water, which have always been given as the characters of ſaline ſubſtances, are properties of many bodies which are not ſaline; as, for example, all mucilages, whether of the vegetable or animal kingdoms: And on the contrary, theſe two properties are ſcarcely perceptible in ſeveral ſaline ſubſtances. Naturaliſts have not ſucceeded better in their definition of ſalts. The cryſtalline form and tranſparency which ſeveral authors have aſſumed as characteriſtic of this claſs, belong likewiſe to many other matters, more eſpecially earths, and are beſides wanting in ſome of the ſalts. It was therefore with great reaſon that Macquer aſſerted, that the limit between ſaline matters and ſuch as are not ſaline is unknown.

However, as it is neceſſary to come to ſome deciſion reſpecting theſe properties, we ſhall give a general account of them before we proceed to the particular hiſtory of each ſalt.

We admit as ſaline ſubſtances all ſuch as poſſeſs ſeveral of the four following properties. 1. A ſtrong tendency to combination, or a very ſtrong affinity of compoſition. 2. A greater or leſs degree of ſapidity. 3. A greater or leſs degree of ſolubility in water. 4. Perfect incombuſtibility. Before we examine each of theſe properties ſingly, it muſt be obſerved, that the ſaline quality of any given body is greater, the more of theſe properties it poſſeſſes, and the greater their intenſity. It muſt not, however, be concluded, that ſubſtances are not of a ſaline nature becauſe theſe properties are ſcarcely evident in them, as it may often happen that two ſpecies, which poſſeſs them in a very ſmall degree, exhibit them ſtill leſs when they come to be united; and there are likewiſe inſtances of the contrary effect taking place; but in theſe caſes, a more varied application of the chemical analyſis, or ſyntheſis, may ſerve to exhibit the ſaline properties more evidently.

§ 1. *Concerning the tendency to Combination, conſidered as a Character of Saline Subſtances.*

The greater number of ſalts have a tendency to combine with many different ſubſtances. It is among the ſalts that the moſt active bodies, with reſpect to combination, are found: For this reaſon the chemiſts have at all times made great uſe of them, and have dignified certain ſalts with the names of ſolvents and menſtrua. This tendency to combination differs greatly in the ſeveral ſpecies of ſalts: Some poſſeſs it in ſo intenſe a degree, that they corrode, diſſolve, or deſtroy every thing they touch, and that even the vitrifiable and quartzoſe ſtones cannot withſtand their action; ſuch are ſeveral of the pure ſalts called acids and alkalis: Others, though they do not ſo ſtrongly tend to combination, nevertheleſs unite with great readineſs to ſeveral ſubſtances: And, laſtly, there are ſalts which do not poſſeſs this property in any ſenſible degree, as is often obſervable in compound ſalts, whoſe principles have a ſtrong affinity with each other, and are mutually ſaturated. It is not to be wondered that ſalts are ſeldom found in nature in a ſtate of purity, when we attend to the effects of this property, of combining with various ſubſtances.

§ 2. *Of Taſte, conſidered as a Character of Saline Subſtances.*

Sapidity has hitherto been conſidered as being ſo far peculiar to ſaline ſubſtances, that many philoſophers have concluded theſe bodies to poſſeſs it excluſively, and that they are the principle of ſapidity in all other bodies; though this opinion is not yet clearly proved, becauſe there are many bodies not at all ſaline, as, for example, the metals, which have a very ſenſible taſte. But though inſtances may be urged of certain ſaline matters which have ſcarcely any taſte, yet it cannot be denied that the moſt eminently ſapid bodies belong to this claſs; for which reaſon we have aſſumed this property as one of the leading characters of ſalts. The ſapidity of ſaline matters varies like their other properties in the different ſpecies. In order to determine its origin, and more eſpecially the cauſe of the differences of its energy, it will be neceſſary to ſhow in what it conſiſts. By ſapidity, we commonly underſtand an impreſſion made on the organs of taſte, by which we determine the good or bad qualities of any ſubſtance with regard to ſalubrity; it is therefore a peculiar action of the ſapid body on the nerves of the tongue and palate of animals. But it may be aſked, whether this property of bodies enables them to act ſenſibly only on the nerves of the tongue, and whether it may not be equally exerted on all thoſe parts of an animal which contain nerves? They who are acquainted with the animal economy cannot deny that the action, which excites the ſenſation of taſte, muſt produce its effect on any nerves whereſoever ſituated, and that it muſt be proportioned to the ſenſibility of the ſubject, and the organs to which it is applied.

" In this way of conſidering ſapidity, we are naturally led to conclude, 1. That its impreſſion will be ſcarcely ſenſible on ſuch parts of bodies as contain few nerves, or whoſe nerves do not poſſeſs a conſiderable degree of ſenſibility, on account of their being covered; as on the ſkin, where they are defended by the reticular membrane and epidermis. It follows, therefore, that the taſte of any ſalt muſt be very ſtrong and active, before it can act ſenſibly upon the ſkin. 2. That the impreſſion will be made with much more efficacy on theſe organs, whoſe nerves are large, numerous, and of a form proper to admit an extended contact, or more violent agitation, and whoſe epidermis is very thin, ſo as to leave the nerves almoſt uncovered. The ſuperior part of the tongue, the palate, and the whole internal ſurface of the mouth, are capable of perceiving the taſte of a great number of bodies, which make no impreſſion on the leſs ſenſible organs of the ſkin. 3. That bodies which have no taſte and no action when applied to the ſkin, may nevertheleſs produce a conſiderable effect on parts more delicately organized, or whoſe nerves poſſeſs a greater degree of ſenſibility, as is the caſe of the ſtomach and inteſtines.

Theſe conſiderations being admitted, we may diſtinguiſh three claſſes of taſtes, and of ſapid bodies, to which all ſaline matters may be referred. The firſt claſs comprehends ſalts of the ſtrongeſt taſte, capable of acting on the ſkin. The impreſſion of this taſte is ſo ſtrong, as to cauſe very acute pain; and if its action be continued for a certain time, the organization of the ſkin is entirely deſtroyed. This taſte is cauſticity; and the ſalts which poſſeſs it are called cauſtic. The ſecond claſs comprehends thoſe whoſe ſapidity is of a mean degree of intenſity, and is not to be perceived but by the organs of taſte; theſe are commonly diſtinguiſhed by different names, as bitter, aſtringent, acid, acrid, urinous, &c. In the third claſs, we ſhall arrange ſaline ſubſtances, whoſe taſte is ſenſible only in the ſtomach and inteſtines: Theſe are not numerous. It is of importance to make ſome obſervations on the relations of theſe ſeveral claſſes of taſtes. And, firſt, It muſt be obſerved, that there are many degrees in each of theſe claſſes by which bodies differ from each other in intenſity of taſte. Thus, among cauſtic ſalts, ſome act much more ſtrongly than others; the former immediately deſtroying the organization of bodies, while the latter require a more conſiderable ſpace of time to produce the ſame effect. This obſervation applies likewiſe to the bitter, aſtringent, and urinous ſalts, as well as to thoſe which have no ſenſible action but on the nerves of the ſtomach. In the ſecond place, In conſidering the diverſities of theſe taſtes, we are naturally led to the concluſion, that the ſeveral taſtes are degrees of the ſame property, from the moſt cauſtic ſalt, to that whoſe action is too feeble to be perceived, but on the highly ſenſible organs of the ſtomach; and this reflection ſeems to ſhow that all taſtes owe their origin to one and the ſame cauſe.

To determine the cauſe of ſapidity, it will be proper to conſider its ſtrongeſt degree, that we may better diſtinguiſh the phenomena, and deduce its mode of action. The inquiry, therefore, relates to the cauſe of cauſticity; a property which has always been a ſubject of conjecture among chemiſts. Lemery obſerving that very hot bodies are exceſſively cauſtic, and likewiſe that ſuch ſalts as poſſeſs this property have been ſubjected to a ſtrong degree of heat in their preparation, attributed the property of cauſticity to the particles of fire, which he ſuppoſed to be depoſited among the particles of bodies. Mr. Baumé eſpouſed this opinion. Meyer, an apothecary of Oſnaburgh, after making a ſeries of inquiries into the nature of cauſtic ſalts, conſtructed an ingenious ſyſtem, or hypotheſis, to which many chemiſts have been much attached, though at preſent it is held in no eſteem. This philoſopher attributed cauſticity to a principle which he conſidered as a compound of fire, and a peculiar acid; this he denominated *cauſticum*, or *acidum pingue*, after the ancient chemiſts. He purſued this principle through its tranſitions and combinations, as Stahl had done before with his phlogiſton; but his ſyſtem was defective in the ſame manner as that of Stahl, as he did not ſucceed better in proving the exiſtence of his *cauſticum*, than Stahl did that of his phlogiſton. Dr. Black, whoſe reſearches were directed to the ſame ſubjects as thoſe of Meyer, gave the finiſhing ſtroke to his doctrine, by clearly ſhowing, that the cauſticity of lime and alkalis, far from being owing to the addition of any principle, *acidum pingue*, as Meyer thought, ariſes, on the contrary, from the ſubtraction of an elaſtic fluid, which we ſhall hereafter deſcribe under the name of the carbonic acid.

Macquer is, beyond controverſy, the chemiſt whoſe inquiries into the cauſe of cauſticity have been attended with the greateſt ſucceſs. The doctrine explained by him on this ſubject, in his *Chemical Dictionary*, is ſo clear, and eſtabliſhed on ſuch concluſive facts, that it is impoſſible to forbear aſſenting to his opinion. After obſerving that cauſtic bodies corrode and deſtroy our organs, by combining with their conſtituent principles, he remarks, that, in proportion as the combination proceeds, the cauſtic body by degrees loſes its force; and that it ceaſes to be ſuch, as ſoon as it has diſſolved as much of the animal matter as it is capable of uniting with. Thus it is, that the pure fixed alkali, or lapis cauſticus, corrodes the ſkin on which it is applied, and after a certain time becomes ſaturated, and ceaſes to act. This ſalt really acts by a chemical force, ſince it produces its effect on the inſenſible ſkin of dead bodies, as M. Poulletier has proved by accurate experiments; and, in general, on all animal ſubſtances, which it diſſolves. Cauſticity, therefore, depends on the tendency to combination; and the effect of this force on our organs is merely the reſult of a combination of the cauſtic matter with the matter of which the organs are formed; in the ſame manner as cauſtic bodies loſe their efficacy, when combined with any other ſubſtance with which they have a tendency to unite; and, in a word, cauſticity is always in proportion to the tendency to combination. Hence it is, that the moſt taſteleſs ſalt owes its want of cauſticity to its being already ſaturated with ſome other ſubſtance; and its taſte will be rendered ſtronger, in proportion to the more or leſs complete ſeparation of that ſubſtance. All the phenomena of ſaline bodies are in proof of this aſſertion, as ſhall afterwards be ſhown.

§ 3. *Concerning Solubility, conſidered as a Character of Saline Bodies.*

Solubility in water has been aſſumed by all chemiſts as one of the leading properties of ſalts: Yet this property, like that of taſte, or the tendency to combination, is ſubject to great varieties. In ſome ſalts it is ſo powerful, that they cannot be deprived of the leaſt portions of water they contain, but by elaborate proceſſes long continued. Others have only a mean degree of ſolubility, which may be aſcertained with conſiderable accuracy, as is the caſe with the neutral ſalts. And, laſtly, there are certain ſaline matters, which are ſo little ſoluble, that they even ſeem in this reſpect to belong to the claſs of earths, and have in fact been conſidered as ſuch by naturaliſts. The limits between thoſe two claſſes of mineral bodies are very difficult to be determined, and chemiſts are not agreed on this head. Mr. Kirwan, in his *Mineralogy*, appears to have adopted the opinion of Bergman, who thinks that all ſubſtances which require more than one thouſand parts of water for their ſolution, ought to be ranked among earths; and that all which are more ſoluble, ought to be eſteemed as ſalts. If this propoſition ſhould be received among chemiſts, as I think it deſerves to be, we ſhall avoid the diverſity of opinions and of language, which has hitherto prevailed, to the diſcouragement and hinderance of ſuch as enter into the ſtudy of this ſcience.

There is the ſame correſpondence between the taſte and ſolubility of ſalts, as there is between this laſt property and the tendency to combination; for the ſolubility in water is an immediate conſequence of the tendency to combination, and muſt therefore follow the ſame laws. It is found, that the more taſte and activity any ſalt poſſeſſes, the more ſoluble it is in water; and this general fact depends on their reſpective nature and properties.

§ 4. *Of Incombuſtibility, conſidered as a Character of Saline Bodies.*

It is more difficult to acquire a clear idea of this property of ſaline bodies, than the others we have been ſpeaking of. They have not yet been conſidered by any chemiſt in this point of view; and many writers have aſſerted, that ſome ſalts, and among them nitre, are truly combuſtible.

To ſhow the fallacy of this opinion, and to prove that all mineral ſalts are perfectly incombuſtible, would require a more intimate knowledge of the properties of theſe ſubſtances, than the reader can yet be ſuppoſed to poſſeſs. Yet as we are of opinion, that this character of ſalts is one of the moſt evident, and the moſt neceſſary to be known, it will be proper in this place to exhibit a ſhort account of the doctrine we hold reſpecting it, which will be explained and incontrovertibly eſtabliſhed in the accounts we ſhall hereafter give of the reſpective ſaline ſubſtances. The valuable experiments of Mr. Lavoiſier ſhow, that ſeveral combuſtible bodies form, by their combuſtion, acids of a particular nature, according to the ſubſtance burned. Combuſtion, as we have already explained, is nothing more than a combination of the baſe of vital air, or oxygen, with combuſtible bodies. All bodies which have been completely burned, that is to ſay, which have combined with oxygen in a ſufficient quantity to be ſaturated, enter into the claſs of incombuſtible bodies; or, which is the ſame thing, their tendency to combine with oxygen being ſatisfied, they are no longer capable of uniting with or abſorbing more. Theſe principles being once proved, if on the one part it be found that many ſalts are the reſidues of various combuſtible matters which have been burned; and if, on the other part, an entire claſs of theſe ſalts be found to contain oxygen, and to exhibit the characters of ſubſtances which have paſſed through the proceſs of combuſtion; it will eaſily be conceived, that they cannot continue to be combuſtible. Theſe aſſertions are founded on a great number of facts, as will hereafter be ſeen; they prove that ſalts are compounded ſubſtances, moſt of them being formed by the union of certain combuſtible bodies with oxygen. And it will be underſtood with equal facility, that this character of incombuſtibility may be conſidered as the moſt certain and invariable property of ſaline matters. The proof of theſe important aſſertions will, we hope, appear complete with regard to the claſs of acid ſalts, in the details which will conſtitute the particular hiſtory of theſe ſubſtances.

There exiſts, nevertheleſs, a claſs of ſalts which appear evidently to be compounded, and do not contain oxygen. Such are the alkalis in general: But they are either compoſed of matters which are themſelves incombuſtible; or, if they contain any combuſtible ſubſtance, as will be ſhown in ammoniac or volatile alkali, it is united to a ſubſtance evidently incombuſtible, which abſolutely prevents this property from being ſenſible in the other ſubſtance.

§ 5. *Concerning the Nature and Compoſition of Saline Subſtances in general.*

Stahl, who paid great attention to the nature of ſaline bodies, was of opinion, that they are formed of water and earth. He collected every fact which was known in his time, and applied them to the illuſtration of his ſublime theory. But that period of improvement has been ſucceeded by another, in which, by the multiplicity of experiments, and the magnitude of the diſcoveries, concerning the influence of air in chemical phenomena, the theory of ſalts as invented by Stahl, and explained with great perſpicuity by Macquer, is no longer found adequate to the explanation of the nature and compoſition of thoſe bodies. We are no longer contented with thoſe diſtant analogies by which the moſt diſcordant facts are united, and which ſerve only to deceive by their illuſive light. It is better to acknowledge our ignorance, than to advance extravagant theories, that muſt ſooner or later be refuted by experiment.

Though the chemical nature of ſalts is not yet perfectly underſtood, and the general facts will not permit us to aſſert, that one ſingle principle is the cauſe and origin of all ſaline bodies, as many eminent philoſophers have thought; yet it muſt be admitted, that we are better acquainted with their compoſition than formerly. It is known that they, for the moſt part, contain a very great quantity of oxygen; and that this fluid is fixed in combination with combuſtible matter, of a different nature in the different kinds of ſalts. There are ſufficient proofs, that many acids are thus compoſed; and it may be ſtrongly preſumed by analogy, that moſt of this claſs of ſalts are compounded in the ſame manner. Water, without being one of the immediate principles of ſalts, is often united, and adheres to them by a very ſtrong attraction. As to the matter of fire, conſidered as phlogiſton, which very great chemiſts have admitted in ſalts, there is too much uncertainty at preſent reſpecting the nature, and even the exiſtence, of this matter, to juſtify the adoption of any decided opinion. It is not the ſame with caloric, which appears to form one of the principles of ſalts, or rather to exiſt in a greater quantity in ſome than in others; ſuch is the general cauſe of the fluidity, fuſibility, and volatility of a great number of ſaline matters.

The preſence of earth in moſt ſalts is not ſhown by any direct experiment; it is only known, that all native ſalts are mixed with a greater or leſs quantity of various earthy ſubſtances. But theſe do not belong to them; they do not, properly ſpeaking, enter into their compoſition, but are, as it were, acceſſaries. We do not, therefore, at preſent know any other principles of ſaline ſubſtances, except ſeveral combuſtible matters, oxygen, ſome incombuſtible ſubſtances, and caloric. It is known, that moſt acids are the reſidues of burned bodies, and that they can contain different proportions of combuſtible matter and oxygen, ſo that they exiſt in very different ſtates, according to the quantity of theſe conſtituent matters. Every thing more which has been ſaid, in treatiſes of chemiſtry, upon the compoſition of ſalts in general, amounts to nothing more than hypotheſes, more or leſs ingenious, but at the ſame time more or leſs remote from truth.

§ 6. *Concerning the Diſtribution, or Methodical Diviſion of Mineral Salts.*

Thoſe ſalts, which belong to the mineral kingdom, are very numerous; many of them are the products of nature, and are formed by the action of fire, water, and air, and by the deſtruction of organized bodies; the greater number, however, are formed by art, or at leaſt have not yet been found among natural products. The methodical treatment of theſe ſubſtances requires that they ſhould be divided into orders, genera, and ſpecies, as has been already done with earths and ſtones; we ſhall claſs all mineral ſaline matters into two orders.

The firſt contains ſuch ſaline ſubſtances as are reckoned ſimple; we have called them primitive ſalts, becauſe they ſerve to compoſe the ſalts of the ſecond order. The ſecond order contains ſecondary, compound, or neutral ſalts, which are formed by the mutual combination of the ſimple ſalts, and are conſequently much leſs ſimple than them.

Each of theſe orders is divided into ſeveral genera, and theſe again into ſpecies. The mineral kingdom, as far as our preſent knowledge extends, conſiſts of nine genera, and at leaſt ninety ſpecies of ſalts, either ſimple or compound, differing from each other. We ſhall proceed to examine theſe in ſucceſſion *.

CHAPTER II.

CONCERNING THE THREE SALINO-TERRESTRIAL SUBSTANCES.

ORDER I. Simple or Primitive Salts.

We diſtinguiſh thoſe ſalts by the name of ſimple or primitive, which were formerly thought to be ſo, and which ſome chemiſts even now continue to call ſimple ſalts; but as accurate experiments have proved that they are for the moſt part compounded, we muſt here take notice, that they cannot with propriety be called ſimple, except when compared with the ſalts of the ſecond order: The epithet primitive is more accurate, becauſe theſe compoſe, when united, the ſalts which we call ſecondary. We divide this order into three genera, comprehending ſaline terreſtrial ſubſtances, alkalis, and acids. The preſent chapter contains an account of the former, and is followed in the ſucceeding chapters by the hiſtory of acids and alkalis.

Genus I. Salino-terreſtrial Subſtances.

The three ſubſtances which compoſe this genus have hitherto been conſidered as earths, whoſe characters manifeſtly reſemble thoſe of ſalts †.

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* There are three ſalino-terreſtrial ſubſtances, three alkalis, and ten mineral acids; and that theſe, united to alumine, the three ſalino-terreſtrial baſes, and the three alkalis, conſtitute ſeventy neutral or compound ſalts. But three of theſe acids may be in two different ſtates, and form neutral ſalts equally different; ſo that about twenty other compound ſalts will be produced.

† We have already ſpoken of them in the lithology; but we did not then conſider them but as forming part of the knowledge of natural hiſtory.

The obvious ſaline properties they exhibit, together with the properties of earths, in a leſs evident degree than either the ſiliceous or argillaceous earths, has induced us to place them before the ſalts, that they may ſerve as a connecting link between the latter and earths, from which they likewiſe differ, in their much ſtronger tendency to combination; as will afterwards be ſeen, in the examination of their properties.

It muſt be obſerved, that, in our examination of the ſalino-terreſtrial matters, as well as that of the primitive ſalts, concerning which we are about to ſpeak, they are ſuppoſed to be perfectly pure, though they are never met with in that ſtate without previous artificial proceſſes. Of theſe proceſſes, however, we cannot yet ſpeak conſiſtently with regularity; the hiſtory of neutral ſalts will ſhow the chemical methods of decompoſing them, as well as the ſimple or primitive ſalts.

This firſt genus contains three ſpecies.

Species I. Barytes.

Barytes was at firſt named ponderous earth, by Meſſrs. Gahn and Scheele, two Swediſh chemiſts, who diſcovered its exiſtence in heavy ſpar. Bergman and Kirwan uſe the Latin word *barytes*. Its ſpecific gravity exceeds 4000, according to Kirwan. This earth is never found in a ſtate of purity, but always combined. It was diſcovered, and conſidered as a particular ſubſtance, by the chemiſts already mentioned. Meſſrs. Margraaf and Monnet imagined it to be of the nature of abſorbent or calcareous earth. The latter, however, obſerved, that it poſſeſſes certain peculiar properties; and was inclined to conſider it as a peculiar earth. Its properties have not hitherto been much examined, at leaſt in its ſeparate and pure ſtate. Its combinations have been more attended to; and it is particularly by the ſalts it forms with acids, and its ſtriking affinity, that it is diſtinguiſhed from every other ſubſtance.

Pure ponderous earth, obtained by the methods hereafter to be deſcribed, is of a pulverulent form, extremely fine, and of a white colour. I have not obſerved that it impreſſes the ſenſe of any peculiar taſte on the tongue.

It is not yet known whether the action of light alters its colour.

The ordinary fire of our furnaces is inſufficient to melt it; it communicates a blue or greeniſh colour to the crucible in which it is heated, and is itſelf lightly tinged with the ſame colour; a property that appears to depend on the mutual action exerted between this earth and clay. M. d'Arcet aſſerts, that a very violent heat melts it in a crucible either of clay or iron. Expoſed to the air, its weight increaſes, and it combines, though very ſlowly, with the carbonic acid of the atmoſphere. The action of oxygen and azote on this ſaline earth is not known; perhaps it may contain azote, as one of its conſtituent parts.

It is ſoluble in water, though very ſparingly, 900 parts of the fluid being required to ſuſpend one part of barytes. Water, thus ſaturated, gives a feeble green colour to the tincture of violets *, and eſpecially to that of mallows or radiſhes. This ſolution, expoſed to the air, becomes covered with a thin pellicle, which, if taken away, is from time to time renewed; the carbonic acid contained in the atmoſphere combining with the ponderous earth, and cauſing this phenomenon, which is ſimilar to what happens with lime-water in like circumſtances, though in an inferior degree. The ſame ſolution, evaporated to dryneſs, leaves the ponderous earth, from whoſe weight the ſolubility of this ſubſtance may be eſtimated. The neceſſity of uſing diſtilled water in this, as well as in every chemical proceſs where accuracy is required, is ſufficiently obvious.

Barytes has but a weak action, either in the dry or humid way, on ſilex and on alumine; it may nevertheleſs facilitate the fuſion of theſe earths, and it aſſumes a blue or greeniſh colour when heated with the latter †.

This ſalino-terreſtrial ſubſtance is found leſs abundantly in nature than either of the others of that deſcription. It is pro-

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* Tincture of violets is a ſolution of the colouring matter of theſe flowers in water: The freſh, or newly made tincture, is a much nicer teſt than the ſyrup of violets; but as the ſyrup may be employed in many caſes to exhibit the preſence of ſaline matter, we ſhall have frequent occaſion to mention it inſtead of the tincture. F.

† It is proper to obſerve in this place, that, for the ſake of order, I do not ſpeak of the combination of two bodies till each has been firſt ſingly deſcribed. In conformity with this rule, I have not in the hiſtory of barytes taken notice of the changes it ſuffers by combination with other bodies, except light, caloric, oxygen, azote, water, ſilex, and alumine; becauſe theſe are the only ſubſtances yet treated of: Its other combinations will therefore be treated of as we advance. This order poſſeſſes the double advantage of being very methodical, and of pointing out what is already known in chemiſtry, as well as what remains to be done to facilitate its progreſs. F.

bable that it may be more abundant than has been ſuſpected. It was formerly known only in the barytic ſulfat or ponderous ſpar; it has been found a conſiderable time ago in England, combined with carbonic acid, and cryſtallized like a tranſparent ſpar. We ſhall deſcribe this ſalt in future. Some modern chemiſts ſuppoſe it to be a calx or metallic oxyd; from its weight, and that of the compounds into which it enters, and likewiſe from the precipitate it affords when Pruſſian alkali is added to its acid ſolution, Bergman, a long time ago, drew the ſame inference. It is aſſerted that M. Gahn, a diſciple of this celebrated chemiſt, has ſucceeded in obtaining this ſubſtance in the form of a regulus; but the fact requires confirmation. Its intimate nature is yet unknown, as no one has ſucceeded either in ſeparating its principles, or imitating it by compoſition. I ſuſpect, as I have before taken notice, that it may contain azote, or the baſe of azotic gas.

Barytes, in a ſtate of purity, has not been applied to any uſeful purpoſe; its ſolutions in water and in acids are employed as re-agents, as will be more fully ſhown hereafter.

Species II. Magneſia.

Magneſia is uſually obtained from Epſom ſalt or ſulphat of magneſia, and abounds in the mother water of nitre, and in a great number of ſtones, &c. It is not found pure in nature, but almoſt always in combination with an acid. Black is the firſt chemiſt who made an accurate diſtinction between this ſubſtance and lime.

Magneſia obtained in a ſtate of purity by the methods to be deſcribed in future, is in the form of a very fine white powder, conſiderably reſembling flour in its appearance and feel; its ſpecific gravity is about 2,33, according to Kirwan; it has no ſenſible taſte on the tongue, but appears to act on the ſtomach, for it is a ſlight purgative; it gives a faint greeniſh colour to the tincture of violets and mallows, and converts turnſole to a blue. The action of light on magneſia has not been accurately noticed, but it does not appear to be conſiderable. When expoſed to a violent heat it does not melt, according to the experiments of M. d'Arcet. Macquer has obſerved likewiſe, that it remains unchanged in the focus of the burning lens of the garden De l'Infante. M. de Morveau obſerved the ſame reſult, after expoſing magneſia for two hours to the moſt violent heat of Macquer's furnace. M. Butini, a citizen of Geneva, who has publiſhed a ſet of valuable inquiries into the nature of the magneſia of Epſom ſalt, has obſerved that this ſubſtance contracts in its dimenſions by a ſtrong heat, ſo that its particles become ſufficiently hard to ſcratch iron. It is alſo affirmed that a ſmall cube formed out of a paſte of magneſia and water, expoſed to the focus of Parker's lens, contracted ſuddenly in all its dimenſions: this property ſhould ſeem to point out ſome reſemblance between magneſia and alumine, with which it is often found naturally combined, as has been obſerved in the hiſtory of ſteatites, aſbeſtos, ſerpentine, &c.

Magneſia heated in a retort loſes nothing but the water it contained; but at the ſame time it acquires a conſiderable degree of phoſphoreſcence, as M. Tingry, apothecary at Geneva, has obſerved. Expoſed to the air, it remains long without alteration. M. Butini placed 10 grains of calcined magneſia in a porcelain ſaucer covered with a paper in a dry chamber, and after near two years it had gained no more in weight than about the eight of a grain. It appears to combine very ſlowly with the carbonic acid of the atmoſphere. It is very ſparingly ſoluble in water, indeed ſo as to be almoſt inappreciable; 4 ounces and a quarter of pure water being left in a bottle for three months, together with one eighth of an ounce of calcined magneſia, firſt boiled together with the fluid, afforded M. Butini a reſidue by evaporation, which he eſtimated to be the one-fourth of a grain.

Mr. Kirwan aſſerts, that it requires 7692 times its weight of water to diſſolve it in the ordinary temperature of the atmoſphere; that is to ſay, about 60 degrees of Fahrenheit's thermometer. Notwithſtanding this difficulty of ſolution, magneſia forms a kind of paſte with water. This paſte is not ductile, but is eaſily broken, and the water is ſoon ſeparated either by heat, or the contact of dry air; the ſolution of magneſia has no ſenſible taſte, and ſcarcely alters the colour of ſyrup of violets.

The action of magneſia on the pure earths is not yet well known; it is decided, however, that it cannot be fuſed with either the ſiliceous or aluminous earths ſingly, but it may with both together.

The mutual action between this and the barytes has not been inquired into.

The intimate nature of magneſia is not more known than that of barytical earth; there is no experiment which can be urged to prove that it is a modification of any other earthy or ſaline ſubſtance, as certain chemiſts have imagined. No one has yet ſucceeded in ſeparating magneſia into its component parts; neither has it yet been formed by ſyntheſis: in the preſent ſtate of chemiſtry it muſt therefore be conſidered as a ſimple ſubſtance.

Pure magneſia, which Dr. Black calls cauſtic, is employed in medicine, as an abſorbent and purgative. It is to be preferred to the ordinary magneſia in thoſe caſes wherein acidities abound, becauſe the carbonic acid contained in the latter is diſengaged by the acids in the firſt paſſages, and produces flatulencies, with all their numerous attendant conſequences: it preſerves fleſh for a long time, and even reſtores putrified bile. Mr. Bergman attributes to it the property of rendering camphor, opium, reſins, and gum reſins, ſoluble in water; though pure magneſia, as we have obſerved, is itſelf ſcarcely ſoluble in that fluid: theſe preparations of Bergman are unknown in France.

Species III. Quicklime.

Quicklime is a white ſubſtance, whoſe parts cohere more ſtrongly together than thoſe of the two ſubſtances laſt treated of; it is uſually in the form of a ſtone of a dirty white; its taſte is burning, acrid, and urinous; and is ſufficiently ſtrong to cauſe inflammation when applied to the ſkin; its ſpecific gravity is about 2,3, and it is pulverulent and friable. It is found native in the vicinity of volcanos, as M. Monnet obſerved among the mountains of Auvergne.

Lime converts the ſyrup of violets to a much deeper green than is produced either by barytes or magneſia; it even almoſt deſtroys this colour, and converts it into a dirty yellow.

Lime expoſed to a very violent heat, as for example, that of a glaſs-houſe, ſuffers no alteration. Parker's burning glaſs, however, appears to have produced a ſlight commencement of fuſion, though the lime was placed on a ſupport of charcoal: its extremities are ſometimes melted when expoſed to a ſtrong heat in a crucible of clay; but this effect is produced by the mutual action of the two earths on each other.

Lime expoſed to the air ſwells, breaks, and is reduced to powder, its bulk being conſiderably increaſed: it is then called lime ſlaked in the air. This change takes place more quickly, and more evidently, according as the air is more humid; it is attended with heat, and the dilatation is ſufficiently ſtrong to burſt caſks or other wooden veſſels, in which lime is contained. If this ſubſtance be examined after being ſlaked, by expoſure to air, it is found to conſiſt of a very fine white powder, remarkably increaſed in weight, while the intenſity of its taſte is diminiſhed. This change is principally owing to the water contained in the atmoſphere, which has a ſtrong tendency to unite with the lime: for if ſlaked lime be brought in a retort to a red heat, the water is expelled, and the lime returns to its original ſtate. The action of water on quicklime is very ſtrong. When a ſmall quantity of this fluid is poured on lime, it is quickly abſorbed, the lime appearing as dry as before: after a ſhort interval of time, it burſts into pieces, producing a degree of heat ſufficient to reduce the water into vapours, with a remarkable hiſſing noiſe. Theſe vapours have a peculiar ſmell, and give a green tinge to paper ſtained with mallows: the lime ſoon falls into a white powder; the heat, the agitation, and the vapours gradually diſappearing. If this extinction be made during the night, or in a dark place, many luminous points are obſerved on the ſurface of the lime. All theſe phenomena are conſequences of the activity with which this ſalino-terreſtrial ſubſtance unites with water; but in order that they may take place, it is required that no more water be uſed than the lime can very quickly abſorb, ſo as to become immediately dry. It ſeems that the diſengagement of heat from theſe two bodies during this rapid union changes their ſtate, and that ſlaked lime in its pulverulent form, contains water in a dry and ſolid ſtate. This dry ſtate of water, which takes place in many combinations, attended with heat, and which produces ſolid compounds, whoſe ſpecific heat is leſs conſiderable than before, has not been enough attended to by chemiſts, or to ſpeak more properly, has been totally unobſerved till lately. When lime, in this experiment, has abſorbed as much water as it can combine with and remain dry, it is called dry ſlaked lime; it then no longer produces heat by the addition of water, but is diſſolved without any ſenſible motion. By mixing with this ſubſtance the quantity of water neceſſary to dilute it, milk of lime is produced; if the quantity of water be ſtill greater, the lime is perfectly diſſolved, and the liquor becomes tranſparent. Mr. Kirwan affirms, that 680 parts of water are required to diſſolve one of lime, at the temperature of 60 degrees.

This ſolution, which is known by the name of lime-water, is clear and limpid; its ſpecific gravity ſcarcely exceeds that of common water; its taſte is acrid and urinous; and it readily converts ſyrup of violets to a green, and even deſtroys the colour. By evaporation in cloſed veſſels, very pure water is obtained, the quicklime remaining behind; but a red heat is neceſſary to ſeparate the laſt portions of water, which are retained with great force: after this treatment, the lime becomes heated by the addition of ſmall quantities of water as before.

Lime-water expoſed to the air becomes covered by a dry pellicle, which gradually increaſes in thickneſs and ſolidity: if this pellicle be taken away, a ſecond is formed, and after that a third, and ſo forth, till the whole of the water is evaporated. Theſe pellicles have been improperly called *cream of lime*; it was formerly thought to be a peculiar ſalt formed by the union of the moſt ſubtle part of the calcareous earth united to water; and much has been written concerning this pretended ſalt of lime. But it is now admitted, ſince the experiments of the celebrated Black, that the ſaline properties of cream of lime are leſs intenſe than thoſe of the lime itſelf; and that it is a peculiar neutral ſalt compoſed of lime, and an acid extracted out of the atmoſphere. Hence it is that the cream of lime cannot be formed without the contact of the air. We ſhall ſpeak of this ſalt under the name of carbonat of lime or chalk. The actions of oxygen and azote upon lime are not known; it ſeems that this baſe abſorbs and fixes a portion of azotic gas; or at leaſt it is probable that it contains the baſe of that ſubſtance.

Lime combines with ſiliceous earth in the humid, as well as in the dry way. When ſand is mixed with lime newly ſlaked, or with quicklime ſprinkled with a ſmall quantity of water at the time of mixing, theſe two bodies become conſiſtent, and form what is called mortar. The ſtate and quantity of the lime, as it is more or leſs perfectly calcined; its previous ſlaking, with a greater or leſs quantity of water, or the ſlaking of it at the time of mixture; the nature of the ſand with regard to its magnitude, its angular or round figure, as well as its degree of moiſture, produce very conſiderable differences in the ſeveral kinds of mortars. Clay baked in bricks, or puzzolana, which is clay baked by volcanic fires, and altered by expoſure to air, are likewiſe added to lime in the making of mortar *.

Though lime, as well as ſiliceous earth, be perfectly infuſible alone; yet if they be heated together, the proportion of the former being much the greateſt, they melt, as has been obſerved by Meſſrs. D'Arcet and Gerhard. Lime likewiſe ſerves as a flux to one third of its weight of alumine: it appears to have a ſtronger affinity with this earth than with ſilex, as Kirwan informs us. The mixture of theſe three ſubſtances melts ſtill more eaſily and completely, than lime with either of them ſingly; ſo that one part of lime, and one of alumine, will ſerve to fuſe two parts, or even two and a half of ſiliceous earth: this fact ſhows the cauſe why many hard ſtones giving fire with ſteel, and of a quartzoſe nature, melt when expoſed to a ſtrong heat; the combination, or ſimple mixture of calcareous earth and clay, is the cauſe of their vitreſcibility.

The mutual action of lime and barytes is not yet known.

One part of calcareous earth enters into fuſion with half a part of magneſia: the glaſs, formed by this mixtnre, afterwards diſſolves, and completely melts a quantity of ſiliceous earth, equal to the lime it contains; equal parts of ſiliceous earth, magneſia and lime, melt therefore by heat into a perfect glaſs.

The intimate nature of lime is not known. The early chemiſts, deſirous of explaining, by phyſical reaſoning, the phenomena exhibited by lime in its combinations, and more eſpecially in its extinction, referred its cauſe to the particles of fire fixed in the calcareous ſtone during its calcination. This was the theory of Lemery. M. Meyer did not admit that pure fire was capable of combining in this manner, and therefore aſſerted, that it exiſted in lime united with a peculiar acid: this ſubtle kind of ſulphur was the *acidum pingue* or the cauſticum of this chemiſt; but his doctrine, though occaſionally brought forward under different names, has been overthrown by a ſeries of experiments, which have completely ſhown its falſity. Many modern chemiſts believe, that the matter of heat exiſts in a combined ſtate in lime, and that the light perceived by Meyer and Pelletier, with the ebullition, the evaporation of the water, and the peculiar fatty ſmell during the extinction of the lime, are conſequences of its diſengagement. Theſe obſervations ſhow, that the principles and compoſition of lime are yet unknown, and that we cannot, with any certainty, decide whether it is the product of an attenuation, or peculiar preparation of the ſiliceous or aluminous earths; though that opinion appears probable to ſome of the greateſt naturaliſts. It ſeems indeed to be out of doubt, that it is formed by marine animals; that its conſtituent parts are united and combined in the water during the life of theſe organic beings; and that azote is one of its conſtituent parts. But it muſt be confeſſed, that this ſketch is not yet ſufficient for the conviction of modern philoſophers, who do not form their opinions decidedly, unleſs in conſequence of repeated and accurate experiments.

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* Conſult *Les Recherches de M. de la Faye ſur la Preparation que les Romains donnoient à la Chaux*, Paris 1777 and 1778, the firſt and ſecond parts. F.

Lime is employed in a great number of arts, and eſpecially in building. In medicine, diluted lime-water is adminiſtered with ſucceſs; in the cure of ulcers, &c. it has been eſteemed as a powerful lithontriptic; but repeated trials have ſhown, that it is not always attended with the deſired ſucceſs, and that its uſe, long continued, produces an alteration in the animal fluids of a ſcorbutic or ſceptic nature.

CHAPTER III.

GENUS II. Alkaline Salts.

WE place alkalis before acids, becauſe they appear to be more ſimple, leſs eaſily decompoſed, and reſemble the ſalino-terreſtrial ſubſtances in their properties. They have an urinous, burning, and cauſtic taſte; turn the ſyrup of violets to a green [a]; give out heat on being united with water. They abſorb the water contained in the atmoſphere as well as its carbonic acid, diſſolve earths, and have a ſtrong tendency to combination [b]. Three ſpecies of alkalis are known; potaſh, or vegetable fixed alkali; ſoda, or mineral fixed alkali; and ammoniac, or the volatile alkali.

Species 1. Potaſh.

The ſpecies of alkali which we denote by the name of potaſh, has been called vegetable fixed alkali, becauſe it is found in large quantities in the vegetable kingdom, though it is likewiſe found in the mineral kingdom; it is uſually called alkali of tartar, becauſe it is obtained in great quantity from this ſubſtance, as ſhall be afterwards ſhown. Potaſh, in a ſtate of purity, was not known before the diſcoveries of Dr. Black. Formerly, to diſtinguiſh this ſalt from the common fixed alkali, it was called cauſtic fixed alkali [a].

This ſalt, when pure, is dry, ſolid, and of a white colour; its taſte is ſo ſtrong, that it deſtroys the texture of the ſkin, and acts as a cautery. It inſtantly converts the colour of ſyrup of violets to a much deeper green than lime water produces in that ſubſtance, and this green is quickly deſtroyed and converted to a brown yellow.

The action of light on the vegetable alkali is not known.

Expoſed to heat in cloſed veſſels, it ſoon becomes ſoft, and melts at the commencement of ignition; if it be then poured out on a ſmooth ſtone, or metallic plate, it concretes into an opake brittle maſs. It is not decompoſable by heat, and becauſe it is not volatilized, except in a very ſtrong heat, ſuch as that of a glaſs-houſe, it is called fixed. It diſſolves a portion of the earthen veſſels in which it is heated.

Expoſed to the air, it ſtrongly attracts humidity, becoming liquid, and gradually aſſuming the ſtate of a neutral ſalt, by combining with the acid of the atmoſphere. This is the cauſe of the augmentation of weight, and the property of effervеſcing with acids, which it acquires by ſuch expoſure. To preſerve it in a ſtate of purity, it muſt be kept in well cloſed veſſels entirely filled with it.

Potaſh diſſolves in water with great facility, producing at the ſame time a high degree of heat, and exhaling a fetid lixivious odour: its ſolution is colourleſs, and affords no precipitate, when the ſalt is very pure. If it be deſired to ſeparate it from its ſolvent, the water muſt be evaporated to dryneſs, in cloſed veſſels; for if the operation be made in open veſſels, it attracts the acid contained in the air, and becomes effervеſcent. This abſorption is ſo rapid, that it is ſcarcely poſſible to leave the ſolution of this ſalt expoſed to the air, without its being partly neutralized: the ſame alteration takes place if it be kept in a bottle, which it only fills in part, and which is often opened. The action of oxygen and of azote upon this alkali is not known.

In the dry way it combines with ſiliceous earth, and forms, by fuſion, the tranſparent body called glaſs. This body has different properties, according to the relative quantities of ſand and fixed alkali it contains. If two or three parts of ſalt be uſed to one of earth, a ſoft glaſs is produced, which attracts the humidity of the air, becomes opake, and at laſt fluid. This glaſs is ſoluble in water, by virtue of the ſuperabundant alkali it contains; and the ſolution is called *liquor of flints*: in proceſs of time it depoſits a portion of the earth it contains, in white ſemi-tranſparent flakes, of a mucilaginous appearance, and ſo light, that they ſubſide very ſlowly. Acids ſeize the alkali, and precipitate the earth, which is called earth of flints. In order that this precipitation may be well performed, the liquor of flints muſt not be too much diluted; for in this caſe the particles of earth are in a ſtate of ſuch extreme diviſion, that they remain ſuſpended in the liquid, which muſt be evaporated before any ſenſible ſubſidence can take place. Several chemiſts think that the earth of flints is not ſimilar to ſiliceous earth, and that it has been changed in conſequence of its union with alkalis; they imagine that it reſembles aluminous earth, and is capable of uniting with acids, and forming aluminous ſalts: this was the opinion of Pott and Baumé; but Scheele has ſhown, that this ſoluble portion of the earth precipitated from the liquor of flints, is obtained from the veſſel of alumine in which the ſiliceous earth and alkali are fuſed.

The art of making glaſs is a proceſs entirely chemical, ſince this ſubſtance is merely a combination of fixed alkali with ſiliceous earth: The purity of the two ſubſtances, their proportion, and their complete fuſion, by the application of heat ſufficiently ſtrong and long continued, are conditions indiſpenſably neceſſary for producing glaſs, which ſhall be hard, tranſparent, without bubbles, and unalterable in the air. We ſhall hereafter have occaſion to take notice of different ſubſtances added to the ſand and alkali, to increaſe their fuſibility, and to produce glaſs of a due degree of weight, tranſparency, and other properties adapted to the uſe it is intended for.

Potaſh does not act ſo ſtrongly on alumine as on ſiliceous earth; but the difference has not been accurately aſcertained.

This ſalt appears capable of combining with barytes, magneſia, and lime; but theſe combinations have not been much inquired into.

Though the potaſh has not yet been decompoſed, yet there are many facts, as ſhall afterwards be explained, which tend to ſhow that it is not a ſimple ſubſtance. Stahl, who conſidered the ſimple ſalts as products of the union of water and earth, imagined that fixed alkali differs from acids only in its containing the latter or earthy principle more abundantly. From this conſideration he explained its dryneſs, &c. It is probable that potaſh is a compound of one of the three preceding earths with azote. Some analogies lead me to believe that it contains lime; but we do not poſſeſs a ſufficient number of facts to admit this compoſition as a demonſtrative truth [b].

Potaſh is employed in ſurgery to corrode the ſkin, and to produce inflammation and ſuppuration in certain caſes.

Species II. Soda.

The name of mineral fixed alkali is given to a ſaline ſubſtance, which poſſeſſes the ſame general characters as the foregoing, and is found in great quantities united with a peculiar acid ſalt, in the waters of the ſea, and in many ſprings. It is likewiſe obtained from vegetables, though much leſs frequently than the preceding. This ſalt has been called marine alkali, becauſe it is one of the component parts of marine or common ſalt; it is alſo called ſalt of ſoda, becauſe it is moſt frequently obtained from that plant [a]. We call it ſimply by the name of ſoda. The taſte of ſoda is equally ſtrong and cauſtic with that of potaſh; it produces a ſimilar change in the colour of ſyrup of violet; and exiſts under a dry and ſolid form [b].

It melts at the commencement of ignition; a violent heat volatilizes it; it acts on almoſt every kind of veſſel in which it is heated.

Expoſed to the air of the atmoſphere, it attracts the humid vapours, as well as the particular acid exiſting there, and gradually becomes neutralized. The action of the oxygenous principle, or vital air, on this ſalt, is not known.

It diſſolves in water, producing heat, and emitting a fetid lixivial odour. Evaporation in cloſed veſſels is the only method of recovering it in a ſtate of purity from its ſolution. This ſolution expoſed to the air abſorbs acid, and becomes quickly neutralized; ſo that to preſerve it pure, it muſt be preſerved in well cloſed veſſels entirely full.

Soda combines readily with ſiliceous earths in the dry way, and forms glaſs. Glaſs-makers have obſerved that this ſalt produces a more fuſible and ſolid glaſs than the vegetable alkali; for which reaſon they prefer it in the manufacture of that commodity: So that what we have ſaid relative to this art under the article potaſh, may be equally applied to ſoda. Laſtly, This alkali, like the potaſh, combines with acids, and with a great number of bodies hereafter to be treated of.

From theſe properties it may be obſerved, that the difference between the two fixed alkalis, in a ſtate of purity, is not very conſiderable, and that their reſpective properties can only be known with certainty from their combinations. When united with the ſame acid, they produce neutral ſalts exceedingly different in all their properties; a circumſtance which ſeems the more ſingular, as it is abſolutely impoſſible to point out any difference between them in their pure and cauſtic ſtate. Bergman adds, as a diſtinguiſhing property of theſe two ſalts, that their affinity with acids is not the ſame, that of the potaſh being the ſtronger; ſo that it is capable of decompoſing ſalts, whoſe baſe is ſoda. This ſubject will again come under examination, when we ſpeak of ſecondary, or neutral ſalts.

The intimate nature or compoſition of the ſoda is not more known than that of the potaſh. The ſame analogies lead me to believe, that this, like the foregoing, is a combination of an earth with azote; and that its characteriſtic properties depend on the difference of its earthy baſe. Perhaps this may be magneſia, as I have for ſeveral years hinted in my lectures, and as M. Lorgna has ſince attempted to prove; but the facts are not ſufficiently numerous, nor even exact enough, to place this opinion in the rank of demonſtrated truths.

It is uſed in the making of glaſs, ſoap, and other compounds [c].

Species III. Ammoniac.

We give the name of ammoniac to the ſalt known by the name of the volatile alkali. It is diſtinguiſhed from the two foregoing by its ſtrong and ſuffocating ſmell, and its ſingular volatility. Like the fixed alkalis, this ſalt was not known in its ſtate of purity before the ingenious experiments of Black and Prieſtley: That which was conſidered as ſuch, is a ſpecies of imperfect neutral ſalt, in a ſolid and cryſtallized form, poſſeſſing ſome of the properties of volatile alkali, but really compoſed of two ſaline ſubſtances*: The character or property of effervеſcing with acids, which was formerly attributed to the volatile alkali, belongs only to this neutral ſalt, of which we ſhall afterwards treat [a].

The liquid known in chemical laboratories by the name of cauſtic, or fluor volatile alkali, and in pharmacy by that of volatile ſpirit of ſal ammoniac, is not pure ammoniac; it conſiſts of this alkali diſſolved in water. Dr. Prieſtley has ſhown, that, by the help of a gentle heat, this liquor may be made to give out a permanent gas; and that the water deprived of this gas loſes its alkaline properties. This aeriform fluid is ammoniac, and is known by the name of ammoniacal gas. Macquer has well obſerved, that this body muſt be examined, in order to arrive at a knowledge of the properties of the volatile alkali.

To obtain this elaſtic fluid, a certain quantity of the liquid ammoniac is put into a ſmall retort, or matraſs of glaſs. A recurved tube is adapted to this veſſel, and the extremity of the tube is plunged beneath the mercury of a pneumato-chemical apparatus; a veſſel of glaſs filled with the ſame metallic fluid being inverted over its orifice. The bottom of the retort or matraſs is then heated, by means of burning charcoal, or the flame of ſpirit of wine. The firſt portion of elaſtic fluid, conſiſting chiefly of the common air contained in the veſſel and tube, is ſuffered to eſcape; and when the ebullition of the fluid is ſtrong, the gas is to be collected. The diſtillation muſt not be urged, ſo as to cauſe the water to paſs in the form of vapour; or a ſmall veſſel ſhould be affixed in the middle of the tube of communication, which, being kept cool, may ſerve to condenſe the aqueous vapour, and cauſes the ammoniacal gas to paſs in a very pure and dry ſtate.

The gas obtained by this proceſs reſembles air in its tranſparency and elaſticity, as long as it is kept above the mercury. It is rather lighter than the air of the atmoſphere; its ſmell is penetrating, and its taſte is acrid and cauſtic; it readily and ſtrongly changes the blue colour of violets, mallows, and radiſhes, to a green; but the alteration produced is leſs than when pure alkalis are uſed; it deſtroys animal life, and corrodes the ſkin, if expoſed for ſome time to its action.

Though it is incapable of maintaining combuſtion, and extinguiſhes bodies which are already on fire, yet it increaſes the magnitude of the flame of a taper before extinction, producing a pale yellow colour round its edge, which proves that alkaline gas is partly inflammable.

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* *Viz.* carbonic acid and ammoniac. *T.*

It is abſorbed by porous bodies, ſuch as charcoal, ſponge, &c.

Prieſtley has diſcovered, that the electric ſpark paſſing through ammoniacal gas increaſes its volume to three times its former quantity, and changes it into hydrogen gas. The cauſe of this change is not yet well known. It appears only that the alkali is decompoſed in this experiment, and that its two component parts, as we ſhall preſently obſerve, are ſeparated, and put into the ſtate of elaſtic fluidity.

Ammoniacal gas is one of the elaſtic fluids which are the moſt ſuſceptible of dilatation by heat.

Atmoſpheric air does not combine with alkaline gas, but only mixes with and dilutes it: The action of oxygenous gas on this gas has not yet been examined.

Water quickly abſorbs ammoniacal gas. If the water be frozen, it immediately becomes fluid, and produces cold; whereas, on the contrary, fluid water becomes heated by combination with this gas. Water ſaturated with gas, or liquid ammoniac, is known by the name of fluor and cauſtic volatile alkali. We ſhall hereafter ſee that the ſtrongeſt and moſt pure volatile alkali is produced by ſaturating diſtilled water with this gas.

Ammoniacal gas has no ſenſible action on earths, or on the ſalino-terreſtrial ſubſtances. Its action on acids, and many neutral ſalts, is very conſiderable, as will afterwards be ſeen.

Liquid ammoniac has the ſame properties as the gas it holds in ſolution, but not in ſo eminent a degree, becauſe the gaſeous being much leſs ſtrong than the fluid aggregation, the tendency to combine will, according to one of our laws of affinity, be much more ſtrong in the gas than in the ammoniac.

This ſalt has been conſidered as a combination of fixed alkali with a combuſtible ſubſtance. This conjecture was founded on the conſideration that ammoniac is produced in many circumſtances by heating fixed alkali with inflammable matters; but it was not known whether the fixed alkali entered as a principle into the compoſition of the volatile alkali, or whether it did not afford a peculiar principle, which, by combining with a portion of combuſtible matter, produces that ſalt. Our knowledge reſpecting the nature of volatile alkali is at preſent ſomewhat more extended. The fine experiment of Dr. Prieſtley, who changed alkaline gas into inflammable gas by the electric ſpark, has cauſed ſeveral chemiſts to ſuſpect that the latter is one of the principles of ammoniac. M. Berthollet, by a ſeries of experimental inquiries, has ſucceeded in proving that this ſalt is a compoſition of hydrogen and azote, retaining a certain quantity of caloric. He was led to this concluſion by the action of oxygenated muriatic acid on the liquid ammoniac, by the decompoſition of ammoniacal nitrat in cloſed veſſels, and by the reduction of metallic oxyds effected by means of ammoniac. Theſe facts will be exhibited more at length in the hiſtory of the compound ſubſtances to which they relate. We ſhall confine our obſervation in this place to the facts, that when combinations of the oxyd of copper and of gold are heated with ammoniac, water and azotic gas are obtained, and the metals are reduced. In theſe operations the ammoniac is decompoſed, its hydrogen ſeizes the oxygen of the metallic oxyds with which it forms water; the metals remain pure, and the azote, the other principle of the ammoniac combining with the caloric, is diſengaged under the form of azotic gas. From theſe experiments, of which we ſhall, in the courſe of the preſent work, give a more ample account, M. Berthollet concludes, that ammoniac contains ſix parts of azote, and one of hydrogen, with a certain quantity of caloric [b].

Ammoniac, diluted with water, is uſed in a great number of diſorders; it is aperient, and powerfully inciſive. It acts ſtrongly on the ſkin; it is preſcribed as a remedy for the bite of vipers, and for cutaneous and venereal diſorders, &c.

As this ſubſtance is acrid and cauſtic, it ought not to be uſed, but with particular care. Externally applied, it is found exceedingly ſerviceable in diſcuſſing tumours, eſpecially ſuch as are formed by coagulated milk, lymph, &c. It readily cures burns, and is often and ſucceſsfully employed in the cure of chilblains, &c. It has been conſtantly uſed under different names, as a very active ſtimulant in ſyncopes, apoplexies, &c. Its uſe, in the latter caſe, ought to be in very moderate quantities; it is not prudent to adminiſter it internally, without previous dilution in a conſiderable quantity of water. Dangerous excoriations have been produced in the œſophagus, and the membranes of the ſtomach, by the volatile alkali being given without this precaution.

NOTES ON CHAPTER III.

[Page 361.]

[a] ALKALIS change the red colour of fernambuc into violet, and the yellow of curcuma into brown.

[b] To theſe properties of alkalis may be added the following:

They have a ſtrong affinity for acids.

They diſſolve animal ſubſtances; and are, on that account, termed cauſtic.

They unite readily with water.

They combine with oils and fats, and render them miſcible with water.

They diſſolve ſulphur, and are cryſtallizable.

SPECIES I. [Page 361.]

[a] THE exiſtence of potaſh in the mineral kingdom has of late been proved by accurate experiments. Klaproth, in the analyſis of the ſubſtance which he terms leucit, found that it formed about 1-5th of that ſtone. In the lepidolite he obtained only 4-100ths. Vauquelin has ſince ſhown that potaſh is contained in a large proportion in the white Veſuvian garnet, and in the lava which ſerves as its matrix. He found alſo a ſmall proportion of this ſubſtance in zeolite from the Ferro Iſlands. Dr. Kennedy of Edinburgh has lately diſcovered potaſh in an analyſis of the pumice-ſtone. See *Beiträge, zweiter band.*; *Annal. de Chem.* Tom. XXII. p. 127. et 274.

The vegetable alkali is procured by lixiviating the aſhes of burnt vegetables, and afterwards evaporating the lixivium to dryneſs in veſſels of caſt iron. The quantity of this ſubſtance obtained from different vegetables varies exceedingly. In general, plants yield more alkali than ſhrubs, and ſhrubs more than the ſolid and denſer trees; the ſolid trunks of trees leſs than their branches, and the branches again ſtill leſs than their leaves. Plants at full maturity yield more alkali than they do either before or after that period. The greater number of the pines and firs afford only a ſmall quantity of vegetable alkali. The natural order of cruciform plants alſo contain little, if any, of this ſalt.

In an economical point of view, it might be highly uſeful to poſſeſs tables of the comparative quantities of alkali which different vegetables afford by combuſtion; but the ſtatements which are to be found in books differ ſo widely from one another, that doubts unavoidably ariſe with regard to the accuracy of the experiments from which they have been deduced. The following tables are the beſt which I have yet ſeen. The two firſt, by Mr. Kirwan, have been extracted chiefly from the reports of the overſeers of the ſaltpetre works in France.

TABLE I.—The Quantity of Aſhes and of Saline Matter obtained from the Combuſtion of 1000 lbs. of different Vegetables, perfectly Dry, and Burned in the Open Fire.

	Pounds of Aſhes.	*Pounds of Salt.*
Stalks of Turkey wheat or maize,	88,6	17,5
—— of ſun-flower,	57,2	20

	Pounds of Aſhes.	*Pounds of Salts.*	
Vine branches,	34	5,5	
Box,	29	2,26	
Holly,	28	2,85	
Elm,	23,5	3,9	
Oak,	13,5	1,5	
Aſpin,	12,2	0,74	
Beech,	5,8	1,27	
Fir,	3,4	0,45	
Fern, in Auguſt,	36,46	4,25	Home.
Wormwood,	97,44	73	Wiegleb.
Fumitory,	219	79	

TABLE II.—Of the Saline Product of 1000 lbs. of the Aſhes of the following Vegetables.

Aſhes from the	*Saline Products.*
Stalks of Turkey wheat or maize,	198 lbs.
—— of turnſole or ſun-flower,	349
Vine branches,	162,6
Elm,	166
Box,	78
Holly,	102
Oak,	111
Aſpin,	61
Beech,	219
Fir,	132
Fern cut in Auguſt,	116, or 125 according to [Wildenheim.
Wormwood,	748
Fumitory,	360
Heath,	115 Wildenheim.

The following table is taken from a memoir by citizen Pertuis, inſerted in the 19th volume of the *Annales de Chemie*. That, as well as the memoir which follows it, contains much practical and uſeful information with regard to the fabrication of potaſh.

A quintal or hundred weight of the following ſubſtances afforded by combuſtion,

	Aſhes.				*Saline Matter.*			
	L.	O.	Gr.	G.	L.	O.	G.	Gr.
Oak,	1	5	5	3	0	2	3	50
Aſpin,	1	3	6	4	0	1	1	45
Yoke elm,	1	2	0	33	0	2	0	4
Beech,	0	9	2	62	0	2	2	51
Nettle,	10	10	6	0	2	8	0	33
Thiſtle,	4	0	5	36	0	8	4	61
Fern,	5	0	1	0	0	10	0	9
Corn thiſtle (cherdon des grains),	10	8	0	0	1	15	3	51
Broad-leaved flags,	4	4	1	40	0	12	6	30
Narrow-leaved ditto,	2	15	4	0	0	6	5	32
Long water ruſh,	3	13	5	24	0	11	4	36
Ruſhes,	4	5	3	0	0	8	1	3

A greater quantity of alkaline ſalt is ſaid to be obtained when the combuſtion is carried on ſlowly than when a briſk fire is employed, and more when the vegetables are burnt in a moderately cloſe furnace than when they are made to undergo this proceſs in the open air. Vegetables which have been long expoſed to the action of air or to rain afford only a ſmall quantity of alkali. They are ſaid to afford alſo more when they are uſed in the green than in the dry ſtate.

Wiegleb having burned in the open air a pound of ſmall pieces of beech wood, obtained 50 grains of aſhes, and 10 grains of ſalt. A pound of the ſame wood was boiled 48 hours, dried and burned; 37 grains of aſhes, and only 3 grains of ſalt, were obtained. But the circumſtances which influence the quantity of alkali obtained by the combuſtion of vegetables ſeem to be as yet but very imperfectly aſcertained.

The product ariſing from the lixiviation of the aſhes is far from being a pure alkali. Beſides an admixture of earthy and extractive matter, it contains a variety of neutral ſalts. The greater part of the earthy matter may be eaſily ſeparated by frequent ſolution in water; the extractive matter is diſſipated by expoſing the ſalt for ſome time to the heat of a reverberatory furnace. By this proceſs the ſalt called *pearl* aſh is prepared. The green or blue tinge which in this ſtate it often exhibits, is ſaid to be derived from manganeſe. A pound of Dantzic pearl aſh = 5760 grains, examined by Mr. Kirwan, was found to conſiſt of the following ingredients:

Carbonic acid,	1290
Moiſture,	414
Sulphat of potaſh,	505
Muriat of potaſh with ſulphat of ditto,	36
Earth,	38
	2283
Pure alkali,	3477
	5760

Unfair traders ſometimes adulterate their aſhes by adding to them a quantity of lime or of common ſalt. As this practice is highly prejudicial in the arts in which alkaline ſubſtances are employed, it becomes an object of ſome conſequence to be able to detect this fraud, and to aſcertain, by a ſure and eaſy method, the proportion of pure alkali contained in any quantity of aſhes. Theſe objects have been ſo happily accompliſhed by Mr. Kirwan, that I cannot do better than uſe his own words. "The preſence of quicklime is eaſily diſcovered by the addition of
" any mild alkaline ſolution, and by the ſame means as eaſily ſeparated. The
" quantity of common ſalt may be found by the addition of a ſolution of ſilver in
" nitric acid to the ſalt to be tried. One hundred grains of common ſalt will pre-
" cipitate 235 grains of the muriat of ſilver.

" To determine the proportion of pure alkali, or alkali combined only with
" carbonic acid and ſulphur, *1ſt*, Procure a quantity of alum, ſuppoſe one pound;
" reduce it to powder, waſh it with cold water, and then put it into a tea-pot;
" pour on it three or four times its weight of boiling water.

" *2dly*, Weigh an ounce of the aſh or alkaline ſubſtance to be examined; pow-
" der it, and put it into a Florence flaſk with one pound of pure water, if the
" ſubſtance to be examined be of the nature of barilla or potaſh, or half a pound
" of water, if it contain but little earthy matter, as pearl aſh; let them boil for a

" quarter of an hour; when cool, let the ſolution be filtered into another Flo-
" rence flaſk.

" 3*dly*, This being done, gradually pour the ſolution of alum hot into the alka-
" line ſolution, alſo heated; a precipitation will immediately appear; ſhake them
" well together, and let the effervеſcence, if any, ceaſe before more of the alumi-
" nous ſolution be added. Continue the addition of the alum until the mixed li-
" quor, when clear, turns ſyrup of violets, or paper tinged blue by radiſhes or by
" lettuces, red; then pour the liquor and precipitate on a paper filter; pour on
" this a pound or more of hot water gradually till it paſſes taſteleſs; take up the
" filter, and let the earth dry in it until they ſeparate eaſily; then put the earth
" into a cup of Staffordſhire ware, place it on hot ſand, and dry the earth until it
" ceaſes to ſtick to glaſs or iron; then pound it, and reduce it to powder in the
" cup with a glaſs peſtle, and keep it for a quarter of an hour in a heat of from
" 400° to 500°.

4*thly*, The earth being thus dried, throw it into a Florence flaſk, and weigh it;
" then put about one ounce of ſpirit of ſalt into another flaſk, and place this in the
" ſame ſcale as the earth, and counterbalance both in the oppoſite ſcale; this be-
" ing done, pour the ſpirit of ſalt gradually into the flaſk that contains the earth;
" and when all effervеſcence is over (if there be any), blow into the flaſk, and
" obſerve what weight muſt be added to the ſcale containing the flaſks to reſtore
" the equilibrium; ſubtract this weight from that of the earth, the remainder is
" a weight exactly *proportioned* to the weight of mere alkali of that particular ſpe-
" cies which is contained in one ounce of the ſubſtance examined; all beſides is
" ſuperfluous matter.

" Alkalis of the ſame ſpecies may be in this manner compared, but alkalis of
" different ſpecies cannot, becauſe equal quantities of alkalis of different ſpecies
" precipitate unequal quantities of earth of alum. Thus 100 parts by weight of
" mere vegetable alkali precipitate 78 of earth of alum, but 100 parts of mineral
" alkali precipitate 170,8 parts of that earth; therefore the precipitation of 78
" parts of earth of alum by vegetable alkali denotes as much of this as the preci-
" pitation of 170,8 of that earth by the mineral alkali denotes of the mineral al-
" kali. Hence the quantities of alkali in all the different ſpecies of potaſhes, pearl
" aſhes, weed or wood aſhes, may be immediately compared by the above teſt, as
" they all contain the vegetable alkali; and the different kinds of kelp or kelps
" manufactured in different places, and the different ſorts of barilla, may be thus
" compared, becauſe they all contain the mineral alkali; but kelps and potaſhes,
" as they contain different ſorts of alkali, can only be compared together by means
" of the proportion above indicated." See *Iriſh Tranſ.* for 1790.

2*d*, The vegetable alkali is procured by the combuſtion of the reſidue from the lees of wine, either by itſelf, or in conjunction with the huſks of the grape. In this proceſs the incineration muſt be conducted with a very gentle fire, otherwiſe the earth naturally contained in theſe ſubſtances will unite with the alkali, and form with it an imperfectly vitrified maſs. From 4000 lbs. of the huſks of the grape (mark de raiſin) the Marquis de Buillon obtained 500 lbs. of aſhes, which, by ſolution in water, yielded 110 lbs. of alkali. The alkali obtained from theſe ſubſtances is much purer than ordinary potaſh, and is known among the French by the name of *cendres gravelées*. See *Journ. de Phyſ. Juillet* 1786.

3*d*, For pharmaceutical purpoſes, the vegetable alkali is uſually procured from the combuſtion of ſmall pieces of tartar rolled up in moiſt bibulous paper. This is an imperfect neutral ſalt, conſiſting of vegetable alkali united to an over proportion of tartarous acid. The acid is diſſipated by expoſing tartar to the heat of a moderate fire till it becomes of a white colour. It is then diſſolved in water, filtered, and evaporated to dryneſs in an earthen veſſel. When cool, it is put into glaſs veſſels, from which the air is carefully excluded. This is done to prevent it from abſorbing the moiſture and carbonic acid of the atmoſphere, for which it has a very ſtrong attraction. In this ſtate it is ſold in the ſhops under the name of *ſalt of tartar*.

The vegetable alkali, in whichever of theſe ways it may have been procured, contains always a greater or leſs admixture of other ſaline ſubſtances. It has therefore long been a *deſideratum* with chemiſts to poſſeſs a method of ſeparating theſe ſubſtances, and of exhibiting this ſalt in a ſtate of abſolute purity; but the ſtrong tendency which the vegetable alkali has to combination renders this extremely difficult. One of the readieſt methods to obtain this alkali pure is to deflagrate the nitrat of potaſh in a crucible with charcoal. This laſt ſubſtance is to be added gradually ſo long as it continues to produce a vivid flame. In this proceſs the nitric acid is decompoſed; its oxygen unites with the carbon to form carbonic acid, part of which is diſſipated by the heat, and part remains in combination with the alkali. At the end of the proceſs it is neceſſary to raiſe the fire a little, ſo that the nitric acid may be completely decompoſed.

But a more common method of purifying this ſalt is that which has long been employed by artiſts and chemiſts in preparing *cauſtic ley*, or a ſolution of the pure alkali in water. It conſiſts in adding, in veſſels of earth or iron, a quantity of boiling water to a mixture of nearly equal parts of alkaline ſalt and of quicklime that has been recently extinguiſhed. This mixture is covered carefully ſo as to exclude the air, and, after cooling, is poured into a glaſs funnel, which has its throat ſhut up by a bit of linen rag. Water is occaſionally poured on this mixture till it paſſes taſteleſs through the filter. When properly prepared, it has no colour nor ſmell, and efferveſces but very feebly, if at all, with ſulphuric acid.

Some conſiderable improvements in this method have been lately ſuggeſted by Le Grange. To filtrate the mixture of alkaline ſalt and lime, he recommends ciſterns of wood or of calcareous ſtone, the dimenſions of which may be varied according to the quantity of cauſtic alkali to be prepared. The mixture is to be kept conſtantly covered with water; and the veſſels in which the ley is ſecured are to be ſlightly cloſed, in order to prevent a free circulation of air. To concentrate the liquor, if required, iron pots may be uſed. When the concentration has arrived at a certain point, the ſulphat of potaſh, which requires for its ſolution a large quantity of water, is ſeparated from the alkaline ley. To remove this, Le Grange propoſes to place a perforated iron ladle at the bottom of the pot, in which this ſalt will be collected. But for a more particular account of theſe improvements, ſee *Annal. de Chem.* Tom. XXII. p. 137.

But the alkali obtained in this way, although highly cauſtic, and fit to be uſed in the arts, and for moſt purpoſes in chemiſtry, is ſtill very impure. When for any nice or accurate experiments alkali is wanted, Le Grange directs the alkali to be prepared by the calcination of the acidulat, or, as it is uſually termed, the *Cream* of Tartar, and by employing the proceſs of purification by ſpirit of wine, firſt recommended by Berthollet.

It had long been known that cauſtic alkali is ſoluble in alcohol; but we are indebted to Berthollet for the happy application which he made of this fact to obtain alkali entirely pure from the ſubſtances with which it is uſually combined. His proceſs is the following: To cauſtic ley evaporated to the conſiſtence of a ſyrup, as much alcohol is to be added as ſhall be ſufficient to diſſolve it completely. A ſmall portion of this alcohol is to be ſeparated by ſubjecting the ſolution to diſtillation. When the retort has been allowed to cool, cryſtals of a more or leſs regular form, mixed with a dark earthy ſubſtance, will be found at the bottom of the retort in a liquor of a yellowiſh colour, which ſwims above them like oil. Theſe cryſtals are generally formed of the carbonat, ſulphat, and muriat of potaſh; the earthy ſubſtance of calcareous earth, with the addition of a little ſilex or iron. The yellowiſh liquor is the ſolution of the pure alkali in alcohol. By ſubjecting it again to a ſlight degree of diſtillation, this liquor is ſeparated into two portions, and remain ſo even after the ſtrongeſt agitation. Lime water produces no change in the ſuperior fluid. When evaporated, its colour becomes deeper; and if in this ſtate it be allowed to remain for ſome time at reſt, tranſparent cryſtals are formed, which have a ſlight yellowiſh tinge. Theſe cryſtals are pure alkali, and produce cold in diſſolving in water. The inferior portion of the liquor precipitates the ſolutions of barytes. Treated in the ſame manner with the former, it alſo afforded cryſtals of alkali, but leſs regular and leſs pure. The alkali procured in this way, though very pure, ſtill retains a portion of colouring matter. But the nature of this ſubſtance has not yet been ſufficiently examined. Berthollet conceives it to be reſinous.

Another proceſs for obtaining fixed alkalis in cryſtals of the greateſt purity has lately been propoſed by Mr. Lowitz of Peterſburgh. The following account of it is copied from the 4th number of Mr. Nicholſon's very valuable Journal.

" A cauſtic lixivium of potaſh is evaporated to a thick pellicle. After the cooling, the foreign ſalt which has cryſtallized is to be ſeparated, and the evaporation of the lixivium continued in an iron pot, as in the preparation of the *lapis cauſticus*. During this ſecond evaporation, the pellicle of foreign ſalts, particularly of carbonat of potaſh, which continues to be formed, muſt be carefully taken off with an iron ſkimmer. When no more pellicle is formed, and the matter ceaſes to boil up, it is removed from the fire, and ſuffered to cool, with continual agitation by an iron ſpatula. It is then to be diſſolved in double the quantity of cold water, the ſolution filtered, and evaporated in a glaſs retort, till it begins to depoſit regular cryſtals. If the maſs ſhould conſolidate ever ſo little by cooling, a ſmall quantity of water is to be added; and it muſt be heated again to render it fluid. After the formation of a ſufficient quantity of regular cryſtals, the fluid, which is very brown, is to be decanted; and the ſalt, after being ſuffered to drain, muſt be rediſſolved in the ſame quantity of water. The decanted liquor muſt be kept in a well cloſed bottle, and ſuffered to become clear by ſubſidence for ſeveral days. It muſt then be decanted for a ſecond evaporation or cryſtallization. The proceſs muſt be repeated as long as the cryſtals afford, with the leaſt poſſible quantity of water, ſolutions perfectly limpid. Theſe ſolutions are to be preſerved in well cloſed bottles, to defend them from the acceſs of air.

" The greateſt difficulty of this proceſs ariſes from the facility with which the lixivium aſſumes the ſolid form. To obviate this inconvenience, a ſmall portion of the lixivium may be concentrated to the point at which it becomes converted into a ſolid maſs by cooling. The ſaturation of a lixivium conſiderably evaporated may be aſcertained by throwing ſmall pieces of this maſs into it during its cooling. When theſe are no longer diſſolved, it is a proof that the lixivium is at the required point.

" This method of proceeding is abſolutely indiſpenſable in the cryſtallization of ſoda, which in other reſpects is made in the ſame manner as that of potaſh. The alkali would not fail, without this management, to form a ſolid maſs during its cooling.

"With regard to the foreign ſalts which are mixed with the potaſh, the greateſt portion ſeparates by cryſtallization after the firſt evaporation of the lixivium ; The reſt is ſeparated during the ſecond concentration by the continual ſkimming of the pellicle. The little which may remain with the potaſh muſt precipitate for want of water of ſolution in a lixivium wherein the alkali itſelf is no longer diſſolved but by its own water of cryſtallization. The property of cauſtic alkalis to diſſolve in highly rectified alcohol, with the excluſion of every foreign ſalt, would afford an excellent means of obtaining this ſalt very pure, if their mutual action did not afford a new ſource of impurity ; for when an alkali abſolutely pure and cryſtallized is diſſolved in ſpirit of wine, even without heat, the fluid aſſumes a very brown colour, which becomes ſtill deeper after decantation from the ſaline maſs.

"The cryſtallization of potaſh is very different, accordingly as the cryſtals are formed with cold or heat. In the firſt caſe, the cryſtals obtained are octahedrons in groups which contain 0,43 water of cryſtallization, and excite by their ſolution in water, even in the ſummer, a degree of cold very near the point of aqueous congelation. In the ſecond caſe, cryſtalline tranſparent very thin blades of extraordinary magnitude are formed, which by an aſſemblage of lines in directions that croſs each other to infinity, preſent an aggregate of cells or cavities, moſt commonly ſo perfectly cloſed, that the veſſel may be inverted without the eſcape of the ſmalleſt drop of the lixivium, though ſometimes included to the quantity of an ounce or two. For this reaſon, it is neceſſary to break this fine cryſtallization, that the fluid may run off. The cryſtals preſent in their regular formation rectangular tetragonal blades, which, as they contain little water of cryſtallization, produce a conſiderable degree of heat when diſſolved in water.

"By expoſing ſuch alkaline cryſtals to a red heat in a very clean crucible they become fuſed, and, after cooling in proper moulds, afford a *lapis cauſticus* as white as ſnow, and extremely cauſtic and deliqueſcent.

"As the cryſtals and the lixivium, during the length of time required to drain the ſalt, may frequently become charged with a portion of carbonic acid, it is adviſable, in order to avoid this inconvenience as much as poſſible, that the lixivium, as ſoon as it is brought to the requiſite point of ſaturation, ſhould be poured into a narrow-necked bottle, and well cloſed therein, to cryſtallize. After the cryſtals are formed, the bottle is to be reverſed without opening, and kept at a temperature rather warm, until the cryſtals are well dried. During the winter, the liquor, after the firſt cryſtallization, continues to cryſtallize without being ſubmitted to a new evaporation, provided only that it be expoſed to a temperature ſomewhat colder than that in which the firſt cryſtals were formed.

"To this account M. Van Mons adds in a note, that cryſtals of cauſtic potaſh may alſo be obtained, by the ſucceſſive evaporation of a ſolution of the potaſh of commerce until the appearance of a light pellicle. The firſt cryſtals which appear are the alkaline carbonat, or mild alkali; and the latter the pure potaſh. In this way the lixivium is reduced into very regular cryſtals to the very laſt portions of ſalt which it contains. Half an ounce of the reſidue of a ſolution of ſeveral pounds ſtill affords very regular cryſtals. It is even remarkable that the latter cryſtallizations are formed with infinitely more facility than the firſt." See *Annal. de Chem.* Tom. XXII. p. 26.

[b] The nature of potaſh ſtill remains unknown. Only a few imperfect experiments have been made to decompoſe it. Analogy, however, would incline us to believe that it is a compound body. Vegetable phyſiologiſts are not agreed whe-

ther this alkali be derived from the ſoil in which plants grow, whether it exiſts uncombined with any acid in plants, whether it be a product of vegetation, or whether it be not rather generated during the proceſs of combuſtion. Will plants yield alkali which have been nouriſhed in pure water? Can it be obtained by macerating vegetables in water? Does charcoal contain any alkali? Previous to the combuſtion of the plants, can any alkali be obtained by adding to them any of the acids to which the alkali has the ſtrongeſt affinity? Under the article *Nitrat of Potaſh*, or *Common Nitre*, we ſhall find reaſon to believe that this alkali is yearly reproduced in certain ſoils expoſed to the influence of the atmoſphere.

SPECIES II. [Page 364.]

[a] This ſubſtance, in combination with carbonic acid, exiſts in conſiderable quantity in various parts of the earth. In this ſtate it has been termed native mineral alkali. In ſome ſituations it is depoſited in beds under the ſurface of the earth, as in China; in others, at the bottom of lakes, as in Hungary and Egypt. Effloreſcent cryſtals of mineral alkali are often found on the inſide of the walls of houſes, in ſubterranean caverns, and on ſoils occaſionally overflowed by waters holding this ſalt in ſolution. The exiſtence of this ſubſtance in mineral ſprings has been known for ſeveral years. Dr. Black found it uncombined, as he conceived, in water brought to him from the hot ſprings in Iceland; but Klaproth, in an analyſis which he has lately publiſhed, aſſerts that this mineral alkali is not free, but exiſts in theſe waters in combination with carbonic acid. The ſame chemiſt found carbonat of ſoda in conſiderable quantity in the mineral waters of Carlſbad. The ſea and ſalt mines are, however, the grand reſervoirs in which this alkali united to the muriatic acid is contained. See *Chaptal*, Vol. I. p. 175.; *Monro, Phil. Tranſ.* Vol. LXI. p. 567.; *Lorgna, Journ. de Phyſ.* 1786 *Juillet.*; *Wiegleb's Chemiſtry, tranſlated by Hopſon*, p. 139.; *Kirwan's Mineralogy*, Vol. II. p. 5.; *Black, Edin. Phil. Tranſ.* Vol. III. *Klaproth Beiträge, erſter band*, ſ. 322.; *zweiter band*, ſ. 99.

The mineral alkali has been hitherto obtained chiefly from the combuſtion of ſea-plants, and of plants which grow in ſalt marſhes. The variety of plants employed for this purpoſe is very conſiderable. In Spain this ſubſtance is procured from the different ſpecies of the *ſalſola ſalicornia* and *batis maritima.* The *zoſtera maritima* is burnt in ſome places on the borders of the Baltic, as is the *anabaſis aphylla* on thoſe of the Caſpian. In this country we burn the various ſpecies of *fuci*. Along with the *ſalicornia* they burn alſo the *chenopodium maritimum* in the ſouth of France.

It ſeems deſerving of notice, that ſome plants, which in their native ſoil yield only vegetable alkali, afford alſo the mineral when they happen to grow in the neighbourhood of the ſea, or in lands occaſionally waſhed with ſea water. Of this kind are the *atriplex halimus* and *portulacoides*, the *reaumuria vermiculata*, the *meſembryanthemum nodiflorum*, *copticum*, *genuliculiflorum*, and *cryſtallinum*, the different ſpecies of the *triglochin*, the *dipſacus fullonum*, &c. The aſhes of the *tamarix gallica* and *germanica* growing at a diſtance from the ſea are ſaid to contain ſulphat of ſoda with the vegetable alkali. The ſame thing has been affirmed of the *ſedum telephium* and *eryngium campeſtre.* See *Bohmer Techniſche Geſchichte der Pflanzen, Erſter Theil*, ſ. 697.

We have as yet but a very imperfect analyſis of the plants from which mineral alkali may be extracted. Chaptal has announced an analyſis of the *ſalicornia*, which is to appear under the article *Verrerie* of the *Encyclopedie Methodique*. Vauquelin has given a ſhort but intereſting account of his experiments on the *ſalſola ſoda*.

In digeſting this plant with diluted nitric acid, and expoſing the mixture to a ſlight degree of heat, he obtained 1. Carbonic acid. 2. Water. 3. Pruſſic acid. 4. An oily matter ſimilar to wax. 5. A white ſubſtance, which has all the characters of an acid, though little ſoluble in water. And, 6. A citron yellow colour in the ſolution, which was increaſed by the addition of an alkali.

An ounce of ſalſola afforded by diſtillation, 1. Water. 2. A yellow fluid ſucceeded by a red oil 3200 cubic inches of elaſtic fluids, of which 66 were carbonated hydrogen gas, the remainder carbonic acid. The liquid product, as well as the gaſes, had a fetid ſmell, gave a green tinge to the tincture of violets, and became white on bringing it into contact with oxygenated muriatic acid. The liquor ſeemed to contain pyrolignite of ammoniac. From this analyſis it is evident the ſalſola contains much azote.

A pound and a half of this plant afforded by combuſtion 3 ounces 2 gr. of aſhes. 500 grains lixiviated and evaporated to dryneſs, left a reſidue of 180 grains. This reſidue conſiſted of the muriat and carbonat of ſoda, in the proportion of 113 parts of the muriat to 60 of the carbonat. The reſidue of the 500 grains which had not been diſſolved, contained ſulphurated hydrogen, carbonic acid, and 91 grains of magneſia, with a ſmall portion of carbon, ſilex and iron. This plant is ſingular, in containing neither lime nor potaſh. See *Journ. de Phyſ.* 1793. *Novembre.*

The mineral alkali obtained from different plants is more or leſs pure, according to the nature of the particular plant from which it has been prepared, and the pains taken in its preparation, to preſerve it from foreign admixtures. The kinds beſt known in commerce are barilla, ſoda and kelp; yet even the barilla, which is reckoned the pureſt of theſe ſubſtances, contains a large proportion of adventitious matter. A pound of barilla examined by Mr. Kirwan, contained of

	Grains.
Carbonic acid, - - -	960
Charcoal, - -	861,82
Calcareous earth, - -	542,86
Magneſia, - - -	127
Alumine, - - -	131,23
Silex, - - -	249,58
Mineral alkali, pure, -	842
Ditto, impure, - -	250
Ditto, with common ſalt, - -	127
Sulphat of ſoda, - -	125
Muriat of ſoda, - -	70
Earth depoſited, - -	20
	4306,49
Water, - - -	1453,51
Total,	5760,00

The aluminous teſt formerly mentioned, will give us pretty exactly the quantity of pure alkali, which any preparation of mineral alkali may contain. 480

grains of mineral alkali precipitate 725 of alumine. By this means Mr. Kirwan was enabled to aſcertain, that 100 lbs. of cryſtallized ſoda contain 20 lbs. of mineral alkali,

Sweet barilla, - -	24
Mealy's cunnamara kelp, - -	3,437
Ditto deſulphurated by carbonic acid, -	4,457
Strangford kelp, - -	1, 25

The native mineral alkali found in Egypt and Barbary is ſaid to be about 50 per cent. ſtronger than common ſoda. Mr. Kirwan conſiders the cryſtals of ſoda as a very fit ſtandard by which to try the ſtrength of the other kinds of mineral alkali, as the quantity of alkali in theſe cryſtals continues at all times very nearly the ſame. See *Iriſh Tranſ. for* 1790.

[b] A ready way to diſtinguiſh the mineral from the vegetable alkali is to drop a ſmall quantity of the of acid ſugar into a ſolution of theſe ſubſtances in water. With the vegetable this acid will form a very ſoluble ſalt; with the mineral one difficultly ſoluble. *Kirwan's Mineralogy*, Vol. II. p. 7.

[c] It has for ſome time been a favourite object with chemical artiſts, to diſcover a cheap, eaſy, and expeditious method of procuring mineral alkali by the decompoſition of the muriat or ſulphat of ſoda. A diſcovery of this kind would indeed be highly beneficial to the arts. The alkali itſelf would not only be purer, but a larger quantity might be obtained, and that with far leſs expence and trouble. Various methods of extracting this alkali are now practiſed in different parts of Europe, but moſt of them are either carefully concealed, or, in conſequence of letters patent, have become the property of private individuals. In the mean time, it may not be improper to take a ſhort review of the labours and conjectures of chemiſts, with regard to a ſubject ſo generally intereſting.

Du Hamel and Margraaf tried in vain to decompoſe the muriat of ſoda with inflammable ſubſtances. They ſucceeded better, however, with the ſulphat of that alkali.

The firſt of theſe chemiſts mixed ſulphat of ſoda with powder of charcoal, and expoſed the mixture to the action of a ſtrong fire. The ſulphuric acid was in part decompoſed, and the mixture reduced to the ſtate of a ſulphure or hepar. Du Hamel added acetous acid to this ſulphure, which diſengaged the ſulphur in combining with the alkali, acetit of ſoda was now formed. The acid of this ſalt was afterwards diſſipated by the fire, and free mineral alkali found as the reſidue. But the alkali prepared in this way is not only very expenſive, but alſo impure, as it contains more or leſs ſulphur, and undecompoſed ſulphat of ſoda. See *Mem. de l'Acad. des Sciences de Paris*, 1736, p. 299.

Margraaf decompoſed the muriat of ſoda by a ſingle affinity. In diſtilling it with nitrous acid, nitrat of ſoda was formed. This ſalt was afterwards deflagrated with powder of charcoal. By lixiviating the reſidue, he obtained cryſtalized mineral alkali. He employed a double affinity to produce this effect, in adding a ſolution of ſulphat of ſoda to a ſolution of lime in the nitric acid. The acids exchanging mutually their baſes, the ſulphuric forms with the lime an inſoluble ſalt. The ſolution containing the nitrat of ſoda, was filtered and allowed to cryſtalize, and the ſalt obtained in this way deflagrated with charcoal. Theſe proceſſes are obviouſly both troubleſome and expenſive. See *Margraaf Opuſcules Chemiques*, Tom. II. p. 331.

Hagen and Bergman diſcovered that the mineral has a leſs attraction for acids than the vegetable alkali. The addition of the latter, therefore, to the acid combinations with the former, afford a ready way of obtaining pure mineral alkali. See *Hagen's Abbandlungen Chemiſchen Inhalts*, ſ. 136. *Bergman. Opuſc.* Vol. III. *de Attractione Electrica*, § 12.

Crell decompoſed ſulphat of ſoda, by adding to it a ſolution of acetit of lime. The acetit of ſoda was afterwards expoſed to a fire ſufficiently ſtrong to diſſipate the acid. See *Chemiſches Journal, Th.* 1. ſ. 94.

Delius reduced by fire ſulphat of ſoda with charcoal to the ſtate of a ſulphure, ſeparated the ſulphur by the addition of the nitric acid, and afterwards deflagrated the nitrat of ſoda with a freſh quantity of charcoal. See *Almanach ſur Apothecker*, 1781. ſ. 129.

Scheele propoſed to decompoſe the muriat of ſoda by the oxyd of lead. Gottling, Achard, and Remmler were at great pains to prove that the proceſs of this excelent chemiſt was impracticable; or, if practicable, too expenſive to be put into execution. See *Weſtrumb. Kleine Abbanlungen*, 1785, ſ. 139.

Weſtrumb expoſed to the action of a ſtrong fire mixtures of one part of muriat of ſoda with from one to ſix parts of charcoal. Theſe mixtures were ſtirred carefully, till the charcoal was wholly conſumed. By lixiviating the reſidue, mineral alkali was obtained in a proportion always correſponding to the quantity of charcoal employed with this alkali. The reſidue alſo contained muriat of potaſh, ſulphat of potaſh, and undecompoſed muriat of ſoda. The decompoſition of the muriat of ſoda in theſe experiments, is to be attributed ſolely to the vegetable alkali which is formed during the combuſtion of the charcoal; for in no inſtance did the quantity of mineral alkali exceed what muſt have been diſengaged by the vegetable ariſing from the quantity of charcoal conſumed.

No mineral alkali could be procured by boiling a ſolution of muriat of ſoda with quicklime.

Weſtrumb mixed from three to four parts of unſlaked lime with one part of muriat of ſoda, and formed the whole into a thick maſs with water. This maſs was carefully kneaded and divided into pieces of about two inches in thickneſs, ſix in breadth, and twelve in length. Theſe were placed in a ſtill ſituation where the air was ſeldom renewed. After ſome time ſmall plumoſe efflorefcent cryſtals were to be ſeen on the ſurface of theſe little maſſes, which, by ſolution and cryſtalization afforded carbonat of ſoda. This proceſs, however, is not only tedious and unprofitable, but to carry it on to any extent would require an immenſe range of buildings.

The gradual decompoſition of the muriat of ſoda by lime, in this proceſs, is one of thoſe anomalous facts in chemiſtry which it is difficult to explain. It forms an apparent deviation from the laws of chemical affinity, for the muriat of lime is decompoſed by the mineral alkali, either in its mild or cauſtic ſtate. This experiment is the more valuable, as it enables us to account for the preſence of mineral alkali in many of thoſe ſituatious in which it is now known to exiſt.

The addition of ſiliceous ſand to the mixture of muriat of ſoda and lime, ſeemed to accelerate the formation of the mineral alkali.

Mr. Kirwan had propoſed to decompoſe muriat of ſoda, by adding to it acetit of lead. The ſolution of lead is to be added, while hot, to a ſolution of the muriat of ſoda, till it ceaſes to produce any farther precipitation. By evaporating the ſupernatant liquor, cryſtals of acetat of ſoda are obtained. From this the acetous acid is expelled by calcining to whiteneſs. Weſtrumb repeated this proceſs, but found it much more expenſive and troubleſome than to decompoſe muriat of ſoda directly by the vegetable alkali.

This chemiſt boiled ſulphat of ſoda in a ſolution of lime. A ſlight decompoſition took place, but the quantity of alkali diſengaged in this experiment, was too ſmall to promiſe any economical advantage.

Sulphat of ſoda, formed into a thick paſte with lime, and expoſed in a ſtill place to the action of air, is alſo gradually decompoſed. The quantity of alkali, however diſengaged, did not ſeem to be greater than is obtained from muriat of ſoda treated in the ſame manner.

In the new method of bleaching, ſulphuric acid is added to muriat of ſoda and manganeſe, in order to procure oxygenated muriatic acid. Sulphat of ſoda is formed. This ſalt is generally thrown away as uſeleſs: but Berthollet, the original diſcoverer of the proceſs, ſays, that he was in poſſeſſion of ſeveral ways of decompoſing it, and of obtaining its alkali in a free ſtate. Theſe proceſſes he was not at liberty to explain, as they had been communicated to him in confidence by the individuals to whom they belonged. Weſtrumb, in conducting a large bleachfield, tried for ſeveral years to decompoſe the ſalt, but afterwards abandoned the proceſs, as being extremely difficult as well as expenſive. The liquor remaining after bleaching, in addition to the ſulphat of ſoda, contains diſengaged muriatic acid, uncombined ſulphuric acid, and a conſiderable quantity of the muriat and ſulphat of manganeſe. The muriatic acid was ſeparated by heat, and the muriat and ſulphat of manganeſe decompoſed by the addition of mineral alkali. The whole of the ſulphat of ſoda thus produced, was calcined with about three parts of powder of charcoal. The calcined maſs was diſſolved in water, filtered, and the ſolution expoſed for ſeveral weeks to the atmoſphere, during which the ſulphur remaining in the ſolution was gradually ſeparated. The ſolution was again filtered, evaporated, and allowed to form into cryſtals of carbonat of ſoda. In this proceſs, Weſtrumb obſerved, that the ſulphuric acid is almoſt wholly decompoſed, and changed into ſulphur, part of which is ſublimed by calcination, part diſſipated in the form of hepatic gas, during the ſolution of the calcined maſs, and part diſengaged during the expoſure to the air by the action of the carbonic acid. This proceſs was firſt recommended by Gren. It is remarkable, that during expoſure the ſulphure of ſoda was not changed, as has been alledged, into a ſulphat by the abſorption of oxygen gas. Weſtrumb aſſerts, in oppoſition to Berthollet, that little or no ſulphat was formed even after an expoſure of ſix months. The alkali prepared in this manner has the ſmell of burnt horn. It retains this ſmell after long expoſure to the air, and after repeated ſolutions and cryſtallizations. It is diſſipated, however, by calcining it in the fire.

Weſtrumb decompoſed the ſulphat of ſoda with the acetat of lead, in the manner of Mr. Kirwan. The decompoſition is perfect, but the expence of the proceſs is too great for the manufacturer.

After much experience, Weſtrumb aſſerts, that the eaſieſt, moſt expeditious, and cheapeſt method of obtaining mineral alkali, is to decompoſe the muriat and ſulphat of ſoda directly, and without an intermedium, by potaſh.

He directs 20 lbs. of muriat of ſoda to be diſſolved in 60 lbs. of water, and to this ſolution 25 lbs. of pure dry potaſh are to be added. This ſolution is to be evaporated till the firſt ſaline pellicle which forms on its ſurface falls to the bottom, and a new one is formed in its place. It is then to be taken from the fire, and kept in a temperature of from 55° to 60° of Fahrenheit. During the cooling, muriat of potaſh ſeparates in great quantity. The liquor is now to be ſtrained through a piece of flannel cloth, and after cooling for an hour or two, a freſh portion of muriat of potaſh, mixed with ſome mineral alkali, will be ſeparated. If the ſolution be now poured into another veſſel, and expoſed in a cool place, pure mineral alkali will be formed in great quantity. The ſalts remaining on the ſtraining cloth are the ſulphat and muriat of potaſh. Theſe are to be waſhed with warm water, and the water carefully preſerved. It, together with the mother water remaining after the ſeparation of the mineral alkali, is to be again ſubjected to the proceſs of evaporation. Every thing is now to be conducted as before. By this treatment, about 25 or 26 lbs. of mineral alkali will be obtained, which ſtill contains a ſmall portion of muriat of potaſh. The whole of this proceſs takes up only ſix or ſeven days. To purify the alkali completely, it is to be diſſolved in boiling water, and evaporated till a thick pellicle forms on the ſurface of the ſolution, it is then to be expoſed to the cold. The muriat of potaſh will be firſt ſeparated, and afterwards the mineral alkali, in large beautiful cryſtals, eaſily diſtinguiſhable by their form. By repeating the evaporation of the liquor remaining after cryſtallization, the whole of the mineral alkali may be ſeparated from the muriat of potaſh, with which it is mixed. By this laſt proceſs about 20 lbs. of pure mineral alkali, in large tranſparent cryſtals, with one and a half of a leſs pure kind were procured.

If the alkali be required in a very pure ſtate, theſe cryſtals may be again diſſolved in diſtilled water, and the proceſs of evaporation and cryſtallization again repeated.

Weſtrumb prefers the muriat to the ſulphat of ſoda in this proceſs, not only becauſe it is cheaper, but alſo becauſe it contains more mineral alkali. The ſeparation of the alkali from the ſulphat, is, however, more eaſily effected; for the ſulphat of potaſh, which is produced in this proceſs, forms a ſalt but little ſoluble in water. See *Chemiſche Abbandlungen*, ſ. 165. 1793.

A very intereſting report on this ſubject is to be found in the 19th volume of the *Annales de Chemie*. It has been drawn up by Lelievre, Pelletier, Darcet, and Giroud, partly from memoirs communicated to them from different parts of France, and partly from experiments and proceſſes which they themſelves had inſtituted.

The firſt proceſs deſcribed in the report, is that of Citizen Leblanc. It conſiſts in decompoſing muriat of ſoda, by means of ſulphuric acid. In a wide and ſhallow leaden veſſel, placed in a reverberatory furnace, and heated, ſo as that the hand cannot be applied to it, 276 lbs. of ſulphuric acid are to be added to 200 lbs. of muriat of ſoda, which had been previouſly reduced to a fine powder. This mixture is to be ſtirred occaſionally with a wooden rake. When the humidity is all nearly diſſipated, and the matter begins to harden, then the fire may be allowed to burn out. The furnaces, in which this proceſs is performed, are conſtructed ſo that the muriatic acid may be diſſipated or collected at pleaſure. In collecting this acid, it may be ſimply united to water, or combined with the volatile alkali ariſing from the combuſtion of animal ſubſtances. In this firſt operation, the decompoſition of the muriat is not complete. The dry matter is therefore to be put into a reverberatory furnace of brick, and ſubjected to a heat ſufficient to fuſe it.

1000 lbs. of the ſulphat of ſoda thus prepared, 1000 of chalk well waſhed, and 550 of charcoal all in powder, are to be mixed together. About 400 lbs. of this mixture are to be introduced at each time into a brick reverberatory furnace. It is neceſſary to break, from time to time, the cruſt that is formed. When it has been reduced by the fire to the ſtate of a ſoft pultaceous maſs, bubbles of ſulphurated hydrogen gas are diſengaged, which burn with great vivacity on coming into contact with the air. At this period, the maſs is to be ſtirred briſkly to conſume all the ſulphur which is formed, and to facilitate as much as poſſible the diſengagement of the hydrogen gas. When this matter in cooling exhibits a fine grain, it is judged to be time to withdraw it from the ſurface. After cooling, it is broken into pieces of different ſizes, and carried to a damp place, where it abſorbs moiſture and carbonic acid from the atmoſphere.

100 lbs. of this matter, diſſolved in water, evaporated, and allowed to cryſtallize, afforded 37 lbs. 8 ounces of cryſtalized ſoda. The water in which it had been diſſolved, when evaporated to dryneſs, 23 lbs. 2 ounces of ſoda, in part cauſtic, and in part aerated with a reſidue of 73 lbs. 7 ounces. 100 lbs. of the reſidue conſiſted of

Carbon	1 lib. 8 ounces.
Sulphur	12.
Chalk	86.

100 lbs. of this ſoda in a dry and pulverulent form, examined by the reporters, was found to contain,

Soda dry, and for the greater part cauſtic,	72 lbs.	8 ounces.
Muriat of ſoda, -	10	
Sulphure of lime, charcoal, and iron,	7	13
Water, - -	9	11

A ſecond proceſs is that of Citizen Alban. The materials he uſes are in the following proportions:

Sulphat of ſoda calcined, -	200 lbs.
Powder of charcoal, - -	40
Pieces of white iron, or iron plate, -	65 lbs.
Charcoal, in the ſtate of *braiſe*, or burning charcoal,	22

The ſulphat of ſoda, and powder of charcoal, are firſt introduced into a reverberatory furnace. When this mixture is properly fuſed, 40 lbs. of the iron are to be added. The maſs is to be ſtirred from time to time, care being taken in the intervals to keep the door of the furnace cloſely ſhut. The matter which at firſt became liquid, now aſſumes a thicker conſiſtence, ſwells and bubbles up, 16 lbs. of the *braiſe* of charcoal are now to be added, and the mixture well ſtirred. Jets of hydrogen gas, as in the former proceſs, are diſengaged. The remaining 25 lbs. of iron, and 6 lbs. of braiſe, are to be added as ſoon as the iron firſt uſed ſeems to be completely melted, and the fire continued till the whole maſs enters into complete fuſion. The melted matter is then to be allowed to run off. The weight of the whole maſs, on coming out of the furnace, is nearly 215 lbs.; ſo that there has been a loſs in all of 134 lbs. The proceſs takes up about three hours. 5 lbs. of this crude ſoda, expoſed to the atmoſphere for 20 days, aſſumed a pulverulent form, and abſorbed 3 lbs. of water and carbonic acid. 100 lbs. of this ſoda lixiviated, and afterwards cryſtalized by evaporation, afforded 71 lbs. 4 ounces of cryſtalized ſoda, 22 lbs. in a dry and powdery ſtate, containing a little iron and charcoal. The reſidue, weighing 86 lbs. 6 ounces, conſiſted of a ſulphure of iron united to a little charcoally matter. This proceſs, the reporters obſerve, is nearly the ſame with that propoſed by Malherb, a Benedictine monk, and of which Macquer gave ſo favourable an account in the year 1778.

"Take," ſays Malherb, "whatever quantity you pleaſe of ſulphat of ſoda, and "add to it 1-10th of its weight of charcoal, and 1-3d of iron, or the ruſt of iron; "fuſe the whole. This fuſed matter hardens by cooling, but will ſoon fall to "pieces in the air. The ſolution of this matter in water has a ſlightly greeniſh "colour, either from a ſmall portion of iron, or of chorcoal. Evaporate the "lixivium, and calcine the reſidue, you will obtain true mineral alkali."

Malherb and his aſſociate Athenas have deſcribed another mode of obtaining this ſalt. It conſiſts in adding 10 lbs. of calcined muriat of ſoda to 14 lbs. of ſlightly calcined ſulphat of iron. The mixture is to be expoſed to the action of fire in a reverberatory furnace, till the muriatic acid is completely expelled. The charcoal is then to be added, and the whole maſs made to enter into fuſion. After cooling, this maſs requires to be repeatedly lixiviated with water, in order to diſſolve all the alkali. The ferruginous reſidue affords by calcination a red brown pigment, which will in part defray the expence of the proceſs. The reporters, in repeating this proceſs, found that nearly 8-100ths of the muriat of ſoda remains undecompoſed.

Athenas ſucceeded alſo in decompoſing muriat of ſoda by copper and zinc; but the expence of theſe metals is ſuch as to preclude entirely their uſe.

Chaptal and Berard have eſtabliſhed a work at Montpellier for decompoſing the muriat of ſoda by lead. They deſcribe their proceſs in the following manner:

Take 400 lbs. of litharge, well ſifted, and diſtribute it equally in four large earthen glazed veſſels; then diſſolve 100 lbs. of muriat of ſoda in 400 lbs. of water. Pour into each of the earthen veſſels 1-4th of the ſaline ſolution, ſo as to form a paſte of a ſoft conſiſtence. The whole is to be left at reſt for ſome hours; but when the ſurface begins to whiten, it is neceſſary to ſtir it well with a wooden ſpatula. Unleſs this be done, the paſte will acquire too great a degree of hardneſs, and a part of the ſalt left undecompoſed.

It is neceſſary alſo to ſtir this paſte as it becomes thicker, and to dilute it with freſh quantities of the ſolution, ſo as to keep it at nearly the ſame degree of conſiſtence. If the ſolution be not ſufficient for this purpoſe, recourſe may be had to common water.

The decompoſition in this way is uſually completed within 24 hours, and the reſult is a very white homogeneous paſte, without clots, and of a volume larger than that of the litharge originally employed. It may be proper, however, to allow this paſte to remain 24 hours longer in the veſſels, and to ſtir it occaſionally, in order to produce a more perfect decompoſition.

In this ſtate the ſoda is cauſtic, and imbibes the muriat of lead. The ſoda may be ſeparated by waſhing this ſalt. For this purpoſe, dilute the paſte with a ſufficient quantity of boiling water, and ſtir the mixture conſtantly in adding it; for without this precaution the paſte will clot, and the lixiviation become extremely difficult. Decant off the liquor, holding the ſoda in ſolution, and filter the remainder through a piece of cloth.

Soda, in a dry form, will be obtained, by evaporating the liquor in iron veſſels. By this proceſs, 65 lbs. of ſoda are procured, much purer than the beſt kinds to be met with in the ſhops, though ſtill mixed with a certain quantity of the muriat of lead, and ſometimes with a little of the muriat of ſoda. This ſoda, which is at firſt very cauſtic, abſorbs carbonic acid from the atmoſphere. The muriat of lead, obtained in this proceſs, may ſerve inſtead of ordinary white lead.

Citizen Carny has propoſed in this proceſs to uſe the red oxyd of lead. 50 lbs. of this oxyd are to be added to 40 lbs. of muriat of ſoda. The mixture is to be put into an iron veſſel placed over a furnace, and kept ſtirring, while the ſalt decrepitates. When the decrepitation has ceaſed, a little water is to be poured on the maſs, and the ſtirring continued till the oxyd becomes white, and till the water riſes about an inch above the maſs of materials. The heat is then to be diſcontinued, and the mixture put, with about 100 lbs. of warm water, into a leaden veſſel. In this it is to be ſtirred anew, and afterwards allowed to depoſite for ſome minutes. We are then to pour off the clear liquor, and evaporate it in a ſecond veſſel of lead. After this, it is paſſed into a third veſſel, which is to be kept covered for three or four days with a piece of woollen cloth. During this time, the muriat of ſoda, which had not been decompoſed, forms into cryſtals; but as it ſtill remains as well as the oxyd of lead with the free ſoda in the liquor, we evaporate this almoſt to dryneſs, and obtain a cauſtic ſoda, holding a little oxyd of lead in ſolution. This oxyd may be ſeparated, by leaving the liquor for ſome time expoſed to the air. The carbonic acid uniting with it, precipitates the lead in a white cryſtalline ſtate. We may be certain that the alkali contains no more lead when we are unable to precipitate it by an acid.

The reſidue after this proceſs contains, 1. Muriat of lead. 2. Muriat of ſoda. 3. A white and uncombined oxyd. 4. Plumbat of ſoda; and, 5. Carbonat of ſoda. By repeated ablutions, theſe ſalts may all be ſeparated, ſo as to leave only the white oxyd and the muriat of lead. The muriat is eaſily reduced by oil, or it may be converted into a beautiful yellow pigment, by fuſing it by itſelf in the fire.

Ribancourt directs a mixture to be made of equal parts of muriat of ſoda and litharge; 100 lbs. ſay of each. The litharge having been reduced to the ſtate of a powder, 4 lbs. of the mixture are to be grounded with 3 lbs. of water. The litharge gradually loſes its colour, and becomes white. At firſt this matter abſorbs only a little of the water; but, in continuing to grind, it acquires a degree of conſiſtence, which renders it neceſſary to add the water ſucceſſively in ſmall portions. When at laſt it becomes a pultaceous maſs, it is to be put into jars, where it is allowed to remain for 24 hours. During this time, it is to be ſtirred occaſionally, and will at laſt acquire a fine white colour.

If we now ſubject this mixture to preſſure, we ſhall obtain 120 lbs. of a ley, 21° in ſtrength. We add to the maſs 120 lbs. of freſh water; ſtir it well, and ſubject it again to preſſure. By this means, we obtain a lixivium of 14°; a third quantity of water will afford a ley of 4°. Theſe liquors are to be mixed and evaporated. During this operation, a pellicle is to be ſucceſſively formed at the ſurface, which is to be removed by a ſkimmer. When the evaporation is finiſhed, the matter is to be left 24 hours to dry. This ſalt does not reſemble ſoda in the form of its cryſtals. It is partly aerated, and partly cauſtic, and contains ſome muriat of ſoda. On being expoſed to the air, it effloreſces, and becomes white. Ribancourt ſubjects it to a ſtrong heat in an earthen pot, and diſſolves it in water. By cryſtallization, perfectly pure ſoda is obtained. The muriat of ſoda which is ſeparated, weighed 16 lbs. 12 ounces, or nearly 1-5th of the whole.

Ribancourt has propoſed a method of obtaining mineral alkali in decompoſing the ſulphat of ſoda by charcoal alone.

Take, ſays he, 100 lbs. of ſulphat of ſoda, reduce it to a powder, and mix it with 25 lbs. of fine powder of charcoal. This mixture is to be introduced into a furnace, and a briſk fire kept up till the matter begins to melt. The heat is then to be diminiſhed, and the matter well ſtirred. When it melts into a ſoft paſte, we give to it a ſudden heat, juſt ſufficient to induce fluidity. The operation is then finiſhed. The matter is taken out when cold, and carried to the place where it is to be lixiviated. This operation takes up about four hours. Much depends on knowing the time when it is proper to withdraw it from the fire; for if it be withdrawn too ſoon, the ſulphat of ſoda is not decompoſed; if too late, the ſulphur burns, and ſulphat of ſoda again is formed. The melting into a paſte is the beſt teſt that the acid has been changed to ſulphur. Ribancourt was, however, obliged to abandon this method, from the great uncertainty which accompanies it, and to have recourſe to iron, as an intermedium to combine with the ſulphur.

In addition to theſe proceſſes, the reporters propoſe to decompoſe muriat of ſoda by martial pyrites, inſtead of the ſulphat of iron. Mixing 10 lbs. of pyrites with 4 of muriat of ſoda, they reduced the whole to a powder, and calcined it for 60 hours in an iron veſſel. During the calcination, a great quantity of ſulphuric and muriatic acids was diſengaged. The maſs acquired a powdery form. It had the appearance of a brown oxyd of iron, and had loſt 3 lbs. 4 ounces of its weight.

By lixiviation, it afforded 4 lbs. 8 ounces of ſulphat of ſoda. The mother water evaporated to dryneſs, left behind a ſaline cryſtallizable maſs of about 4 ounces in weight. It conſiſted of undecompoſed muriat of ſoda, ſulphat of ſoda, and muriat of iron.

The reſidue of this lixivium, filtered and dried, was a brown oxyd of iron, 6 lbs. 12 ounces in weight. In heating this, a conſiderable quantity of ſulphureous acid was diſengaged. This oxyd the reporters propoſe to uſe, along with the charcoal, in the farther decompoſition of the ſulphat of ſoda. By conducting the proceſs in this manner, we ſhall ſave both time and expence.

Common pit coal, or, what is ſtill better, peat or turf, may be uſed inſtead of charcoal, and have beſides the additional advantage of giving out volatile alkali by combuſtion.

The reporters varied this proceſs, by mixing 10 lbs. of pyrites with 32 of coarſely powdered pit coal; and to this maſs they added water, containing 6 lbs. of the muriat of ſoda. This mixture was formed into balls, which were burnt on a gridiron in a reverberatory furnace, by a little lighted charcoal placed under them. The incineration took up 13 hours. Their aſhes, by lixiviation, afforded 6 lbs. of cryſtallized ſulphat of ſoda.

100 lbs. of pyrites, 30 of peat, with 6 1-half of muriat of ſoda, treated in the ſame manner, afforded 7 lbs. of cryſtallized ſulphat of ſoda.

In this country various methods of obtaining mineral alkali are followed by different chemiſts. Some of theſe methods are carefully concealed, while others of them are but very imperfectly explained in the letters patent which thoſe who practiſe them have obtained. There can be little doubt that all of them, however, are conducted on the ſame principles with the proceſſes we have already ſo fully deſcribed. See *Repertory of Arts and Manufactures.*

After this long detail, it ſeems ſcarcely neceſſary to remark, that, in preparing mineral alkali on a large ſcale, we muſt often be directed in the choice of our means by local circumſtances, by the nature and price of the materials that are within our reach, and by the value and demand, not only for the alkali itſelf, but alſo for the other uſeful ſubſtances that may be procured in this intereſting proceſs; for in this, as well as in every other mercantile concern, calculations with regard to the expence and the profits muſt neceſſarily form the baſis of every rational enterpriſe.

SPECIES III. [Page 365.]

[a] AMMONIAC, or the volatile alkali, is formed during the ſpontaneous decompoſition of animal ſubſtances. Many plants alſo give out volatile alkali, while they paſs to the ſtate of putrefaction. Combined with different acids, it exiſts in many mineral waters, in coal, and in various other kinds of ſtrata. The ſtrata, however, in which it exiſts, are generally obſerved to contain ſome marks of animal or vegetable bodies. See *Kirwan's Mineralogy*, Vol. II. p. 7.

For the purpoſes of commerce and medicine, volatile alkali is prepared only from the animal kingdom. Being obtained by diſtillation from the horns of animals, it has been long known in the ſhops by the name of *ſpirit of hartſhorn.* In this ſtate it is very impure, containing ſome oil and much carbonic acid. In order to obtain it free from theſe ſubſtances, it is neceſſary to diſſolve it in muriatic acid, and afterwards to diſengage it from this combination by the addition of a fixed alkali, or of lime. Two parts of burnt lime, and one of the cauſtic alkaline ſalt, are the proportions to be added to one part of the muriat of ammoniac. This mixture is introduced into a retort, to which a ſeries of receivers, containing pure diſtilled water, is to be adapted. The ſlighteſt heat is ſufficient to diſengage it in the ſtate of gas. This gas paſſes over into the receivers, combines with the water, and ſaturates it. The quantity of gas which the water can abſorb has not yet been accurately aſcertained. In this ſtate it is preſerved in the ſhops under the name of *cauſtic volatile alkali*, or *ſpirit of ſal ammoniac with quicklime.*

b Dr. Prieſtley, from his experiments, was led to infer that alkaline gas contains about one fourth of its weight of azotic gas. To Dr. Prieſtley we owe alſo the intereſting diſcovery that metallic oxyds may be reduced in alkaline gas. In expoſing *maſſicot*, oxyd of lead, in contact with alkaline gas, to the action of a burning lens, the lead was always revived, and a reſidue left of only pure azotic gas.

Glaſs of antimony was revived in the ſame circumſtances, though it was found impoſſible to produce this effect in ſimple hydrogen gas.

Scales of iron were revived in alkaline gas, with the loſs of a ſmall portion of their weight.

During the revivification of *red precipitate*, oxyd of mercury, in alkaline gas, the Doctor particularly remarks that water was certainly produced. See *Prieſtley's Experiments and Obſervations*, Vol. II. p. 368,—402.

Van Marum ſeparated hydrogen gas from alkaline gas by means of the electric ſpark. See *Deſcription d'une Grand Machine Electrique*, p. 128.

Scheele had obſerved that volatile alkali was decompoſed when added to nitric acid and mangaueſe, or when muriat of ammoniac was diſtilled with the oxyd of that metal. He remarked, beſides, that the volatile alkali was decompoſed by the oxyds of gold, mercury, and ſome other metals; and that during theſe decompoſitions azotic gas was conſtantly evolved. See *Scheele on Air and Fire*, p. 137.; *Scheele's Chemical Eſſays*, p. 110.

Bergman attributed the phenomena of fulminating gold to the decompoſition of ammoniac and the ſudden evolution of azotic gas.

By conſidering carefully theſe experiments and opinions, that excellent chemiſt Berthollet was led to determine more accurately the true nature and the proportion of the component parts of volatile alkali.

He introduced 2 ounces of the dry nitrat of ammoniac into a ſmall retort in connection with a pneumatic apparatus. By expoſing this ſalt to the heat it was decompoſed, nitrous gas in large quantity diſengaged, and about 3 gros 65 grains of water were formed. As the nitric acid does not contain any hydrogen, the volatile alkali, he concluded, was the only ſource from which this ſubſtance could be derived.

In adding oxygenated muriatic acid to ammoniac, Berthollet obſerved that a very lively effervescence took place. The elaſtic fluid diſengaged was pure azotic gas. In this experiment the oxygen of the oxygenated muriatic acid combines with the hydrogen of the ammoniac; while azote, the other component part of ammoniac, is diſengaged. In proof of this explanation, it may be remarked, that if a ſmall quantity of ammoniac be added, it will be wholly decompoſed; but if a large quantity, muriat of ammoniac will be formed. Berthollet alſo found that the oxyd of copper diſſolved in ammoniac was conſtantly revived by expoſure to heat. The azotic gas of the alkali was diſengaged, while its hydrogen united with the oxygen of the oxyd to form water. See *Mem. de l'Acad. pour* 1785, p. 316.

Woulfe found that volatile alkali is wholly decompoſed in diſtilling muriat of ammoniac with nitric acid. See *Journ. de Phyſ.* Nov. 1787.

Dr. Milner diſcovered that when ammoniacal gas is made to paſs into a gun barrel filled with oxyd of manganeſe, and kept in a red heat, that the volatile alkali was decompoſed, and that nitrous, inſtead of ammoniacal gas, paſſed out of the tube. In this beautiful experiment, while one portion of the oxygen of the oxyd of manganeſe unites with the azote of the ammoniac to form nitric acid, another portion combines with the hydrogen to form water.

Dr. Milner alſo obtained nitrous gas by paſſing ammoniac gas over calcined ſulphat of iron. See *Phil. Tranſ.* Vol. LXXIX. p. 300.

Seguin, Vauquelin, and Sylveſter, repeated this experiment; but, inſtead of an iron, they uſed a porcelain tube. A conſiderable quantity of nitrat of ammoniac, in the ſtate of vapour, azotic gas, and water, were produced. See *Annal. de Chem.* Tom. VI. p. 295.

Van Mons decompoſed volatile alkali by adding a ſmall quantity of this ſubſtance to the vitrified oxyd of lead, and expoſing them for ſome days to a heat of about 40° of Reaumur. The volatile alkali gradually diſappeared; but at the end of the experiment 6 grains of nitrat of ammoniac were formed. See *Journ. de Phyſ.* 1790 *Juin.*

Fourcroy has made a variety of intereſting experiments on the mutual action of metallic oxyds and ammoniac. A part of the oxygen of the oxyd unites with the hydrogen of the ammoniac to form water, while the azote, diſengaged under the gaſeous form, occaſions a ſlight effervefcence. This action was very evident with the oxyds of manganeſe, mercury, iron, and lead, but leſs ſo with thoſe of zinc, antimony, biſmuth, and cobalt. See *Annal. de Chem.* Tom. II. p. 219.

Chaptal obſerved that the oxyds of arſenic were reduced to the metallic ſtate by digeſtion with ammoniac. During the diſengagement of the azotic gas and the formation of water, the arſenic appears under the form of octahedral cryſtals. See *Chaptal's Elements of Chemiſtry*, Vol. I. p. 185.

Morveau, in diſtilling 936 grains of nitrat of ammoniac, obtained 203 grains of water in addition to that which the ſalt originally contained. Much nitrous gas was evolved. It is needleſs to remark, that, in this experiment, the nitric acid and ammoniac were ſeverally decompoſed. See *Grundzüge von Scherer*, ſ. 264.

A ſlight detonation with inflammation is produced by bringing oxygenated muriatic acid into contact with ammoniacal gas; azotic gas is diſengaged, and muriat of ammoniac produced. See *Journ. de Phyſ.* 1789 *Mars.*

Such are the facts by which the decompoſition of ammoniac has been eſtabliſhed. We ſhall now mention a few to prove its formation. The ſmell of this ſubſtance had often been obſerved by chemiſts to ariſe from combinations into which there was no reaſon to believe it had entered as a component part.

Pott found, that, in treating zinc in a particular manner with nitric acid, ammoniac was produced.

Dr. Higgins relates, that, by moiſtening filings of tin with moderately ſtrong nitric acid, and afterwards adding to them a quantity of fixed alkali or lime, a conſiderable portion of volatile alkali was diſengaged. In this experiment the nitric acid and water muſt both have been decompoſed. The oxygen from theſe ſubſtances united with the metal to form an oxyd, while the azote of the nitric acid united with the hydrogen of the water to form ammoniac. See *Higgins's Chemical Experiments and Obſervations*, 1786.

Kirwan obſerved that volatile alkali was formed by mixing ſulphurated hydrogen gas with nitrous gas.

But it is to Dr. Auſtin we are indebted for the firſt accurate and deciſive experiments on this ſubject. Into a cylindrical glaſs tube, filled with and inverted over mercury, he introduced ſome azotic gas, and afterwards ſome iron filings moiſtened with diſtilled water. The hydrogen gradually evolved from the water combined with the azotic gas, and formed volatile alkali. Dr. Auſtin remarks, that, in this experiment, the water ſeemed to be decompoſed more ſpeedily than when iron and water were ſimply mixed by themſelves.

Volatile alkali was formed in a ſhorter ſpace of time when nitrous inſtead of azotic gas was employed. The nitrous gas, deprived in this manner of its azote, was converted into oxygen gas.

This experiment ſucceeded alſo in atmoſpherical air, requiring, however, a longer period of time. Whenever iron ruſts in contact with water in the open air or in the earth, Dr. Auſtin conceives that volatile alkali muſt neceſſarily be produced. This remark will enable us to explain readily the occurrence of volatile alkali in mineral waters, coal, &c. See *Phil. Tranſ.* Vol. LXXVIII. p. 379.

Hauſſman, in paſſing nitrous gas through a quantity of precipitate of iron, obſerved that this gas was ſpeedily abſorbed. During this proceſs the colour of the iron was changed, and ammoniacal gas diſengaged. See *Journ. de Phyſ.* 1787 *Juin.*

Dr. Milner obtained a ſmall quantity of volatile alkali by heating a ſaturated ſolution of copper in diluted nitric acid, to which ſome iron filings had been added. See *Phil. Tranſ.* Vol. LXXIX.

Morveau introduced a pound and a half of Malacca tin, with five pounds ſeven drachms three grains of pure nitric acid, into a retort, the neck of which was fixed in a receiver, ſurrounded with ice, and connected with a pneumatic apparatus. By ſubjecting this mixture to heat, a nitrat of ammoniac was formed, which contained 72,32 grains of volatile alkali. See *Nachträge von Scherer*, ſ. 519.

Dr. Auſtin, Van Marum, and Hildebrandt, tried, but in vain, to produce ammoniac by the direct combination of its component parts in their elaſtic ſtate.

CHAPTER IV.

GENUS III. Acids.

ACIDS are diſtinguiſhed by their ſour taſte, when diluted with water; they redden blue vegetable colours. Many acids exiſt in the gaſeous form; they unite with great rapidity to alkalis; their action on inflammable ſubſtances is much ſtronger than that of the laſt mentioned ſalts, and moſt commonly reduces them to the ſtate of bodies which have been burned. As inflammable matters, more eſpecially metallic ſubſtances, are found to contain a large quantity of oxygen after having been ſubjected to the action of acids, while the acids themſelves become converted into combuſtible bodies; it may be concluded that this genus of ſalts is much leſs ſimple than has hitherto been thought, and that they are in general compoſed of inflammable matter, combined with oxygen.

We are acquainted with ten ſpecies of mineral acids, very different from each other: The phoſphoric acid is likewiſe found in this kingdom, united to iron, to lead, and to lime.

The carbonic acid,
The muriatic acid,
The fluoric acid,
The nitric acid,
The ſulphuric acid,
The boracic acid,
The molybdic acid,
The tungſtic acid,
The arſenic acid, and
The ſuccinic acid.

We ſhall here treat of the ſix firſt, which are in general the beſt known and moſt abundant; the four others ſhall be treated of elſewhere.

Species I. The Carbonic Acid.

We give the name of carbonic acid to a very abundant acid, which, being often found in the aeriform ſtate, was originally called *fixed air* by the Engliſh, *mephitic acid* by Mr. Bewly, *mephitic gas* by Macquer, *aerial acid* by Bergman, and *cretaceous acid* by Bucquet[a]. We ſhall preſently explain the reaſon and the utility of the denomination we have adopted.

This acid has not always been conſidered as ſuch. Its leading properties were perceived by Paracelſus, Van Helmont, Hales, &c.; but it is to Black, Prieſtley, Bewly, Bergman, and Chaulnes, that we are indebted for the certain knowledge of its acidity.

The carbonic acid gas poſſeſſes all the more obvious qualities of air, and exiſts in the atmoſphere, of which it forms a ſmall part*. Like air, it is inviſible and elaſtic; it cannot be diſtinguiſhed from this fluid when encloſed in a glaſs veſſel, or when it floats in the air. It is found diſengaged and in a ſtate of purity in ſubterraneous cavities, as in the Grotto del Cane, &c. It exiſts in a ſtate of combination in a great number of natural bodies, ſuch as mineral waters, and ſeveral neutral ſalts[b]: Great quantities are produced in the ſpirituous fermentation[c]; it is likewiſe produced in the proceſſes of reſpiration, and of the combuſtion of charcoal; and laſtly, all the parts of plants, more eſpecially the leaves, continually emit it while in the ſhade.

This acid, though elaſtic and tranſparent, differs greatly from air, even in its phyſical properties; its ſpecific gravity is double that of air[d]: Hence it may be poured, like other denſe fluids, from one veſſel to another; and for this reaſon it flows out of the cock after a caſk of wine has been drawn off. Its taſte is briſk, and ſubacid; animals which reſpire it die inſtantly; and all bodies in a ſtate of combuſtion are extinguiſhed by being plunged in this fluid. It colours the tincture of turnſole with a clear red; which, however, diſappears by expoſure to air, in proportion as the acid evaporates. It does not alter the colour of violets, becauſe its action is too feeble to produce a ſenſible change in deep and fixed colours.

The force of affinity of this acid is in general very weak, as it yields to every other acid: It ſuffers no change by expoſure to light, or at leaſt the change is too ſmall to be perceived.

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* Mr. Lavoiſier concludes, from his ingenious experiments, that atmoſpheric air conſiſts of vital air, carbonic acid, and azotic gas, uſually in the following proportions:

Vital air,	27
Carbonic acid,	1
Azotic gas,	72
Total,	100

Heat dilates this fluid, without changing it in any other reſpect [e].

It mixes with pure or vital air, but without combination; and forms a mixture which may be reſpired for a certain time, provided the carbonic acid do not exceed the third part of the whole: It may be adminiſtered in this manner as a remedy for diſorders of the lungs.

It combines with water, though ſlowly. When theſe two fluids are agitated together, and their ſurfaces of contact are by that means multiplied, they unite more readily, and form an acidulous liquor. Bergman calls this ſolution *aerated water;* but this name may be with equal propriety applied to water containing true air, by way of diſtinguiſhing it from water which has been deprived of that fluid by ebullition. Water diſſolves a greater quantity of carbonic acid the colder it is; but this ſolution is limited to a certain quantity: The coldeſt water cannot abſorb more than its own bulk of it [*].

Water charged with carbonic acid is ſomewhat heavier than diſtilled water; it ſparkles when agitated; its taſte is briſk and acidulous; and it reddens the tincture of turnſole. It boils readily, and is decompoſed by the heat, its acid eſcaping in the form of an elaſtic fluid. The contact of air produces the ſame effect the more quickly, as its temperature is higher [f]. It is neceſſary, therefore, for the preſervation of this liquid, that it ſhould be kept in a cool place, in well-cloſed veſſels, or under a ſtrong compreſſion.

This acid ſolution is abundantly found in nature, where it conſtitutes acidulous and gaſeous waters, ſuch as thoſe of Pyrmont, Seltzer, &c.

As this acidulated water is a remedy proper to be uſed in putrid diſorders, both internally and externally, philoſophers have contrived various apparatus for ſpeedily impregnating water with the whole quantity of carbonic acid it is capable of diſſolving. A proceſs for acidulating water was firſt publiſhed by Dr. Prieſtley in the year 1772. Dr. Nooth has invented a machine for producing this effect, which has been ſince ſucceſſively improved by Mr. Parker and Mr. Magellan. This is at preſent to be met with in all philoſophical laboratories. A good deſcription and engraving may be ſeen in the fifth volume of Prieſtley's Experiments.

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[*] Water ſubjected to preſſure takes up a larger quantity of this acid, in proportion as the preſſure is greater; hence it ſhould ſeem, that the acid may exiſt in the pores of water without loſing its elaſtic form. T.

The carbonic acid does not act on ſiliceous earth. It is well known that this earth does not cryſtallize in acidulated water, as was aſſerted ſome years ago.

The carbonic acid unites with alumine, barytes, and magneſia, and forms ſeveral kinds of neutral ſalts, which we ſhall afterwards examine.

A combination of this acid with the ſolution of lime in water is conſtantly attended with a phenomenon, which forms a criterion of the preſence of this acid. When it comes in contact with the lime-water, white clouds are immediately produced, which increaſe in bulk, and form a very abundant precipitate. Theſe clouds ariſe from the combination of the carbonic acid with the lime, with which it forms chalk, or carbonat of lime. This new ſalt, being ſcarcely at all ſoluble in pure water, falls to the bottom: Lime-water is therefore a teſt for diſtinguiſhing the nature and quantity of the acid we are treating of. If an additional quantity of the acid be added after the precipitate is formed, this exceſs will cauſe it to diſappear by a ſecond ſolution. Chalk diſſolved in water, by a ſuperabundance of the carbonic acid, is precipitated by boiling, by expoſure to air, and, in a word, by every proceſs which can take away this exceſs. Hence it is that cauſtic fixed alkalis and pure ammoniac, poured into a ſolution of chalk by carbonic acid, precipitate the chalk by abſorbing that exceſs of acid.

Acidulated water poured into lime-water produces exactly the ſame effect.

The carbonic acid combines rapidly with the three alkalis. If a ſmall quantity of cauſtic fixed alkali, in a liquid ſtate, be put into a veſſel full of this acid obtained from chalk, or taken from the ſurface of a vat of beer in a ſtate of fermentation, and the orifice of the veſſel be quickly cloſed with a wetted bladder, the veſſel being then moved in ſuch a manner as that the liquid alkali may be ſpread over its internal ſurface, the bladder will be obſerved to be preſſed inwards, the abſorption of the carbonic acid by the alkali cauſing a vacuum within the veſſel. This combination is attended with heat; and the ſides of the glaſs are in a ſhort time covered with cryſtals, which become larger and larger. We call this ſalt *carbonat of potaſh*, or of *ſoda*, according to the nature of the alkali which has been uſed. Theſe two ſalts, which are truly neutral, were formerly called by the names of ſalt of tartar, and ſalt of ſoda: We ſhall ſpeak of their properties in the next chapter.

The contact of ammoniacal gas, and the aeriform carbonic acid in cloſed veſſels, likewiſe produces an inſtantaneous vacuum; it is attended with heat, and forms a thick white cloud, which becomes adherent to the glaſs, either in the form of cryſtals, or of an incruſtation. It is a true imperfect neutral ſalt, which we ſhall diſtinguiſh by the name of carbonat of ammoniac, and which was formerly called concrete volatile alkali, Engliſh ſalt, &c.

The carbonic acid adheres to theſe baſes with different degrees of force. According to Bergman, its affinity with barytes is the ſtrongeſt: after which follow in ſucceſſion, lime, potaſh, ſoda, magneſia, and ammoniac. The phenomena on which Bergman has eſtabliſhed this gradation of affinity will be ſeen when we ſpeak of neutral ſalts.

The nature and compoſition of the carbonic acid have for ſome years paſt engaged the attention of chemiſts. Prieſtley, Cavendiſh, Bergman, and Scheele, appear to be of opinion that it is formed by the combination of pure air and phlogiſton; but as the exiſtence of this laſt mentioned principle has been juſtly doubted by many celebrated French chemiſts, we cannot think that this theory ought to be admitted, or can ſolve all the objections that can be made to it. I formerly thought that the carbonic acid might be a compound of inflammable gas and pure air; but the diſcovery of the nature and decompoſition of water has ſhown the improbability of this hypotheſis, and Lavoiſier has ſubſtituted a demonſtrated truth in its ſtead[g].

This chemiſt, to whom the ſciences are indebted for the vaſt number of ingenious and accurate experiments he has made, burned a determinate quantity of charcoal, in glaſs veſſels filled with vital air, over mercury. The charcoal was deprived of all its hydrogenous gas, by a previous calcination in cloſe veſſels, as he had obſerved, that without this precaution drops of water were obtained, by which the accuracy of the reſults was affected. The combuſtion began by the help of a quarter of a grain of fungus placed on the charcoal, in contact with a very ſmall particle of phoſphorus: a bent wire, whoſe end was heated red, being paſſed through the mercury, ſerved to ſet the phoſphorus on fire; this communicated to the fungus, and the latter to the charcoal. The inflammation was very rapid, and attended with much light. The whole apparatus being cold, Lavoiſier introduced cauſtic fixed alkali in the fluid ſtate, which abſorbed the acid formed during this combuſtion, and left a portion of vital air as pure as at the beginning of the experiment. This chemiſt thinks, that in the preſent operation the oxygenous principle, whoſe combination with caloric forms vital air, combines with the carbon, and produces the carbonic acid, while the other principle is diſengaged under the form of heat and light. Some aſhes remained, and the quantity of acid formed, exceeded the weight of the vital air made uſe of, by a quantity equal to the loſs ſuſtained by the charcoal. From many experiments of the ſame nature, made in various circumſtances, Lavoiſier concludes, that a centenary of carbonic acid, ſo termed from its origin, is compoſed of about twenty-eight parts of pure carbon, and ſeventy-two parts of oxygen.

The reſpiration of animals, in his opinion, diſengages from the blood a true carbonaceous matter, which combining with the oxygen of the atmoſphere, forms the carbonic acid conſtantly produced during this proceſs; and that the combination of the carbon of ſugar, with the oxygen of water, is the cauſe of the production of the carbonic acid in the vinous fermentation.

Several philoſophers have obſerved, that this acid, in its elaſtic ſtate, poſſeſſes the property of preſerving animal ſubſtances, by retarding putrefaction, and even diminiſhing its effects after it has commenced. Hence it was, that M'Bride ſuppoſed that it unites with the putrid ſubſtance, and reſtores the acid it had loſt during the time of putrefaction. This laſt phenomenon, according to his doctrine, ariſes from the natural decompoſition of organic bodies, and the diſſipation of the carbonic acid, which he calls *fixed air*: for which reaſon he ſuppoſed that the application of this acid was indiſpenſably neceſſary to compenſate the loſs ſuſtained in the animal economy, and to reſtore the fluids to their former ſtate, when changed by heat and motion. He admits the exiſtence of this acid in freſh vegetables, eſpecially ſuch as are ſuſceptible of fermentation, as the decoction of barley, which has been ſuffered to germinate, or the infuſion of raiſins, &c. all which he thinks are equally ſerviceable in ſeptic or ſcorbutic diſorders.

Water impregnated with carbonic acid, has likewiſe, in ſeveral caſes, been ſucceſsfully preſcribed in putrid, bilious fevers. It is ſaid that the Engliſh uſe the carbonic acid, mixed with common air, in diſorders of the lungs.

It has been ſtrongly recommended as a lithontriptic, or ſolvent of the ſtone in the bladder; but we are not in poſſeſſion of any authenticated facts in proof of its efficacy in France. Beſides which, this effect is contrary to the diſcoveries of Scheele and Bergman upon the ſtone of the bladder, as we ſhall elſewhere obſerve.

The public prints contain accounts of ſeveral inſtances of the cure of the cancer made in England by the application of the carbonic acid. We can nevertheleſs aſſert, that this means has been uſed by ourſelves and others, without ſucceſs, ſeveral times. After the firſt application, the cancerous ulcer exhibits a more favourable appearance; the ſanies, which commonly flows, becomes white, conſiſtent, and laudable; the fleſh aſſumes a lively colour: but theſe flattering appearances do not continue; the ulcer ſoon returns to its former ſtate, and paſſes through the uſual changes with unabated violence. It is to the firſt diſcovery of this acid by Dr. Black that we muſt fix one of the moſt brilliant epochas of chemiſtry. To determine the influence of this diſcovery on the ſcience, we ſhall here offer the following remarks:

Firſt, It has added one to the number of acids. *Secondly*, It has ſhown the cauſe of the effervеſcence which mild alkalis, chalk, calcareous ſpar, and magneſia, produce with ſtronger acids than itſelf. *Thirdly*, It has cauſed a diſtinction to be made of all alkaline matters into two ſtates, the ſtate of purity or cauſticity, and the mild ſtate, having the property of effervеſcence. *Fourthly*, It has greatly enlightened the hiſtory of the elective attractions of acids for ammoniac and lime. *Fifthly*, It exhibits the firſt inſtance of an acid which prefers lime to fixed alkalis. *Sixthly*, The hiſtory of mephitic caverns, in which animals cannot live, is become very clear and ſimple, in conſequence of this diſcovery. *Seventhly*, The analyſis of waters has been rendered more perfect from the accurate knowledge of ſuch as are called gaſeous, ſpirituous, acidulous, and in conſequence of that knowledge we have ſucceeded in perfectly imitating them. *Eighthly*, It has thrown great light on the ſolution of iron in many waters, and on the means of procuring martial waters entirely ſimilar to thoſe in nature. *Ninthly*, It has exhibited a claſs of neutral, earthy, alkaline, and metallic ſalts, in which the carbonic acid is a principal part; and which are diſtinguiſhed in this work by the generic name of *carbonats*. *Laſtly*, It has opened a new field to the reſearches of chemiſts and natural philoſophers, and has excited that ardour to which we are indebted for all the brilliant diſcoveries made ſince that period. The name of Black will ever be memorable in the annals of chemiſtry, and will endure as long as the ſcience itſelf.

As to the production of this acid by the electric ſpark in vital air, it muſt be obſerved, that in the experiments of Mr. Landriano, the iron, which ſerved as a conductor to the electric fluid, is the cauſe of this phenomenon by virtue of the plumbago, carbure of iron, it contained, and the ſmall quantity of acid produced is an additional proof that this explication is well founded. There are, doubtleſs, many caſes in which the carbonic acid is decompoſed and reſolved into its principles like the other acids [h]. Thus it is, for example, that water, charged with this acid, is much better adapted for the production of vital air by means of leaves expoſed to the rays of the ſun; becauſe the vegetable organization abſorbs the carbonaceous principle, while the light, acting like heat, contributes to the ſeparation of the oxygen in the form of vital air [i]. It is ſtill more remarkable, that certain oxyds of iron, diſtilled in the pneumatic apparatus, afford only the carbonic acid in paſſing to the ſtate of æthiops or black oxyd of iron. This depends on the carbon or the plumbago which many ſpecies of iron contain. The carbon abſorbs a portion of the oxygen of the iron, with which it forms the acid that is diſengaged. Theſe newly diſcovered facts will be more fully explained in ſome of the following chapters of this work.

Species II. The Muriatic Acid.

The fluid called by the name of *marine acid* [a], *ſpirit of ſalt*, or *liquid muriatic acid*, in our laboratories, has a taſte ſufficiently ſtrong to corrode our organs when concentrated, and when much diluted impreſſes a ſenſation of acidity and ſtipticity. It is abſoſutely colourleſs when pure. When it is of a red or orange colour, as moſt of the muriatic acid of the ſhops is, it is owing to certain combuſtible bodies, moſt frequently iron. This acid is obtained from marine ſalt or muriat of ſoda, as we ſhall ſee in the hiſtory of that ſubſtance. If it be ſtrong and concentrated, it emits a white vapour or fume. When expoſed to the air, it has a lively and penetrating ſmell, which, when diluted or faint, reſembles that of citron, or the apple called golden rennet: it is then called the fuming muriatic acid. The fumes are much more viſible when the air is moiſt. If a bottle containing this acid be opened, and the hand brought near its orifice, a ſenſible heat is perceived, which ariſes from the combination of the acid vapour with the water in the atmoſphere. Muriatic acid ſtrongly reddens the ſyrup of violets, and all blue colours of vegetables, but does not deſtroy them. This liquid, however concentrated and ſmoking, does not conſiſt of the pure diſengaged muriatic acid, but contains that acid united to much water. Dr. Prieſtley has eſtabliſhed the truth of this, by teaching us how to obtain the acid in the permanent form of gas over mercury, at the preſſure and temperature of the atmoſphere: we muſt therefore attend to the properties of this gas, which in fact is the muriatic acid unmixed, and in a ſtate of perfect purity.

The muriatic acid gas is obtained by heating the fuming muriatic acid in a retort, whoſe neck is plunged beneath the orifice of a veſſel filled with mercury. This gas, which is much more volatile than water, paſſes into the veſſel. It has the uſual properties of common air, but is heavier. Its ſmell is penetrating, and it is ſo cauſtic, as to inflame the ſkin; it ſuffocates animals, extinguiſhes the flame of a taper, firſt enlarging it by the addition of a green or bluiſh circumambient flame. It is abſorbed by porous bodies.

Light does not ſeem to produce any ſenſible change in it; it is rarefied, and its elaſticity is prodigiouſly augmented by heat. Atmoſpheric air, mixed with muriatic acid gas, included in glaſs veſſels, produces fumes or vapours attended with a ſlight degree of heat; a proof that combination takes place. The more humid the air, the denſer theſe vapours appear; and for that reaſon they are not at all ſeen at the ſummits of lofty mountains, where the air is very dry, according to the obſervation of M. d'Arcet: the white vapours, which are exhaled from liquid muriatic acid, are therefore a conſequence of the water contained in the atmoſphere. This liquid acid, as well as its gas, does not abſorb vital air when in the elaſtic ſtate, though there are methods of combining them with oxygen, as we ſhall ſhow hereafter. It is aſſerted, that, by ſtrongly agitating the liquid muriatic acid with vital air, a portion of the latter is abſorbed [b].

Muriatic acid gas eagerly unites with water. Ice abſorbs it very quickly, being inſtantly melted. Water is ſtrongly heated during its union with this gas; when ſaturated, it perfectly reſembles the liquid acid from which the gas was obtained by heat. It emits white vapours, is colourleſs, reddens ſyrup of violets, &c. We ſhall hereafter ſee that this elaſtic fluid, received in pure water, produces the pureſt and moſt concentrated liquid muriatic acid [c].

Muriatic acid gas has no action on ſiliceous earth; it combines with alumine, forming muriat of alumine.

It unites with the ſalino-terreſtrial ſubſtances, with which it forms barytic, magneſian, and calcareous muriats.

Its combination with potaſh produces the *febrifuge ſalt of Sylvius*, or muriat of potaſh; with the mineral alkali of ſoda, it forms marine or common ſalt, or muriat of ſoda.

Muriatic acid gas, in contact with ammoniacal gas, in veſſels over mercury, becomes much heated; the fluids mutually penetrate each other, and a white cloud is immediately formed; the mercury riſes in the veſſels, and their internal ſurfaces are covered over with ramified cryſtals of ſal-ammoniac, or muriat of ammoniac. If the two gaſes are very pure, they completely diſappear when they aſſume the concrete form, and the diſengagement of heat has taken place [d]. This experiment is one of thoſe which prove, 1*ſt*, That all bodies, which paſs from the liquid to the elaſtic ſtate, abſorb at the ſame time a certain quantity of the matter of heat or caloric; for the muriatic acid does not become gas without heat. 2*d*, That elaſtic fluids, in their tranſition to the liquid or ſolid ſtate, give out the heat they took up in their aerification. 3*d*, That the elaſtic ſtate depends on this abſorbed and combined heat; and that all aeriform fluids are compounds to which the fixed heat, or caloric, gives this form, as we have already explained elſewhere [e].

The muriatic acid abſorbs the carbonic acid; the mutual action of theſe two bodies has not yet been properly examined; it

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is known, that the carbonic acid is leſs powerful than the muriatic, and is diſengaged from all baſes by this laſt. As to the different degrees of attraction for the various alkaline baſes, Bergman lays them down in the following order: Barytes, potaſh, ſoda, lime, magneſia, ammoniac, alumine.

The intimate nature of the muriatic acid, or the principles which enter into its compoſition, are not yet known. Beccher thought it to be formed of the ſulphuric acid, united to *mercurial* earth, becauſe he obſerved that this acid has a ſtrong affinity to all ſuch bodies as he ſuppoſed to contain that principle, ſuch as arſenic, mercury, &c. Stahl made no addition by way of explaining this opinion of Beccher. And among the numerous and ingenious experiments of the moderns, there are not any which throw much light on this ſubject. As its acidifiable baſe is unknown, it cannot be determined whether two ſtates exiſt with reſpect to the ſaturation of this baſe by oxygen: the firſt in which the baſe would be ſaturated, and the acid the ſtrongeſt; the ſecond in which there ſhould not be the ſame quantity of oxygen, and the acid ſhould be weaker, as we have obſerved with reſpect to the ſulphuric and ſulphureous, the nitric and the nitrous acids. The preſence of oxygen has not even been demonſtrated in the muriatic acid; and it is only by the force of analogy that we are led to admit its exiſtence in this acid [f].

Scheele is the only chemiſt who has made any diſcovery of importance reſpecting the different ſtates in which this acid exiſts: this philoſopher (in 1774) having diſtilled muriatic acid from the oxyd of mangaueſe, obtained the acid in the form of a yellowiſh gas, of a very penetrating ſmell, and capable of diſſolving all metals with great facility, not excepting mercury and gold. He thinks that in this operation the manganeſe, which he takes to be very greedy of phlogiſton, ſeizes that of the muriatic acid; for which reaſon he calls the elaſtic fluid, *dephlogiſticated marine acid*, and ſuppoſes it to diſſolve gold, in conſequence of its ſtrong affinity to phlogiſton. There is, however, no direct experiment which ſhows the preſence of the inflammable principle in this acid; and in the year 1780, I ſuſpected that the vital air of the manganeſe is united to the muriatic acid, as may be ſeen in the articles Aqua Regia, Manganeſe, &c. in the firſt edition of theſe elements. Berthollet has proved the truth of this, by a very accurate and ingenious ſeries of experiments.

The muriatic acid, poured on the oxyd of manganeſe, affords yellow vapours before the application of heat. If the retort be heated, and the vapours received in veſſels containing water plunged in ice, a very ſmall quantity is diſſolved, and the water is very ſoon ſaturated; the gas which continues to be produced takes a concrete form, and falls to the bottom of the liquid in cryſtals. The water, in this experiment, muſt be cooled almoſt to freezing, becauſe the ſlighteſt heat diſſolves this concrete ſalt, and occaſions it to eſcape in the form of bubbles.

The oxygenated muriatic acid, in a liquid form, or diſſolved in water, has, according to Berthollet, an auſtere, but not acid taſte. It deſtroys the colours of vegetables, and renders them white, without firſt cauſing them to become red. It does not diſengage the carbonic acid from its baſes, and conſequently cauſes no efferveſcence when applied to them: in a word, it has no acid properties.

The oxygenated muriatic acid efferveſces when heated with quick lime, vital air being diſengaged. The reſidue is calcareous muriat, which depends on the diſengagement of the gas of the oxygen, which ſaturated the acid. The oxygenated muriatic acid produces an efferveſcence in its combination with cauſtic ammoniac; but water and azotic gas are the reſult of this combination. In this experiment the oxygenated acid and the ammoniac are both decompoſed; the hydrogen, which is one of the principles of the ammoniac, unites with the ſuperabundant oxygen of the muriatic acid and forms water; while the azote, the other principle of the ammoniac, uniting with caloric, is ſeparated under an elaſtic form, and produces the efferveſcence which is obſerved in this experiment. In ſhort, the oxygenated muriatic acid converts metals into oxyds, and diſſolves them without efferveſcence: in deſtroying vegetable colours, it paſſes to the ſtate of common muriatic acid. All theſe experiments prove, that the *dephlogiſticated* marine acid of Scheele is a combination of this pure acid with vital air or oxygen, and may, with greater propriety, be called aerated or oxygenated muriatic acid, as I propoſed in the firſt edition of theſe Elements. Berthollet has not yet determined the quantity of oxygen abſorbed by the muriatic acid in theſe experiments *, in order to give to it the properties we have mentioned. He has diſcovered, ſince his firſt eſſay, that the oxygenated muriatic gas, received in a ſolution of carbonat of potaſh, forms a neutral cryſtallizable ſalt; which detonates upon charcoal like nitre, and even more ſtrongly, which affords very pure vital air, or oxygenous gas, by the action of fire, and leaves after theſe two eſſays the muriat of potaſh. Theſe experiments prove more and more the theory which I firſt explained nine years ago, of the nature of the oxygenated muriatic acid; ſince the detonation of the oxygenated muriat of potaſh is manifeſtly owing to the ſuperabundant oxygen. Soda forms only a deliqueſcent ſalt with the oxygenated muriatic acid[g].

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* *Rozier's Journal*, May 1785.

The muriatic acid is employed in the arts, and more eſpecially in the art of aſſaying in the humid way †. In medicine it is adminiſtered, in a very diluted ſtate, as a diuretic and antiſeptic; and it is the chief ingredient in the remedy of the Prior de Chabrieres for ruptures. It is externally uſed as an eſcharotic; and likewiſe in gangrenes of the throat, aphthæ, &c. Mixed with a certain quantity of water, it conſtitutes a bath for the feet, which is a great ſecret with ſome practitioners, and is uſed for the purpoſe of removing the ſeat of the gout from the nobler to the inferior parts.

The oxygenated muriatic acid has not been known a ſufficient time to apply it to any uſe. Berthollet thinks that it may be uſed for the purpoſe of diſcovering, in a few minutes or hours, the effects which expoſure to air will produce on certain dyed ſtuffs; and that their durability may by that means be aſcertained. He has lately propoſed it to be uſed in bleaching cloths and thread; and the firſt trials made at Paris, on a ſcale of conſiderable magnitude, promiſed to be ſucceſsful. It may likewiſe be uſed for ſpeedily bleaching yellow wax, and particularly the green wax of our iſlands[h].

Species III. The Fluoric Acid.

The fluoric acid, diſcovered by Scheele, received its name from a kind of neutral ſalt, called fluor ſpar, from which it is obtained[a].

This acid, in a ſtate of purity, has the form of gas; in which ſtate, therefore, we ſhall examine its properties. It is heavier than air, extinguiſhes fire, and deſtroys animal life; has a penetrating ſmell, ſimilar to that of muriatic acid gas, but more powerful; and its cauſticity is ſuch, that it corrodes the ſkin in a ſhort time; light does not ſenſibly alter it; and heat dilates it, without producing any other change.

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† See *Bergman's Eſſays*, Vol. II. either in the Engliſh tranſlation, or original Latin.

The addition of atmoſpherical air has the ſame effect on this as on the muriatic acid, producing a white vapour, which is more or leſs abundant, in proportion to the humidity of the atmoſphere.

The fluoric acid gas unites to water very rapidly, and with heat; a peculiar phenomenon attends their combination, when the acid has been extracted in glaſs veſſels, namely, the precipitation of a very fine white earth, of a ſiliceous nature: It therefore ſeems that this acid, in the ſtate hitherto deſcribed, is very far from being pure. For this reaſon, I am inclined to think that it can only be had pure, in depriving it, by means of water, of the earth it took up during its volatilization. This gas, diſſolved in water, forms the liquid fluoric acid, whoſe ſmell and cauſticity are very powerful when the water is ſaturated. This liquid acid ſtrongly reddens ſyrup of violets. It poſſeſſes the ſingular property of corroding and diſſolving ſiliceous earth, according to Scheele and Bergman. Though the fluoric acid gas, in its union with water, depoſits a great quantity of ſiliceous earth, it ſtill retains a ſomewhat conſiderable portion, which is precipitated by alkalis[b].

Dr. Prieſtley obſerved that fluoric acid gas corrodes and penetrates glaſs; which circumſtance obliged him to make uſe of very thick glaſs in his experiments. Macquer thought that this acid does not produce this effect but in its ſtate of gas; and that in its liquid ſtate, or when combined with water, it ceaſes to poſſeſs that property: His opinion is founded on the conſideration, that water precipitates the ſiliceous earth, which is held in ſolution by the fluoric gas. But as water does not entirely ſeparate it, we ſee that the liquid fluoric acid can act on the earthy part of glaſs, and upon ſiliceous ſtones.

The liquid fluoric acid may be decompoſed in the ſame manner as ſpirit of ſalt, by heating it in a retort, whoſe neck is plunged under the orifice of a veſſel filled with mercury. The fluoric acid gas is obtained, and the water remains pure.

The two French chemiſts, who, under the name of Boulanger, publiſhed, in the year 1773, a ſeries of experiments on the fluor or vitreous ſpar, are of opinion, that this acid is nothing elſe but the muriatic acid, combined with an earthy ſubſtance, ſeparable only by water. But Scheele has unanſwerably confuted this opinion, and conſiders it as a peculiar acid, ſufficiently diſtinguiſhed from all others by its combinations. This laſt opinion is almoſt univerſally received [c].

The fluoric is the only mineral acid which poſſeſſes the property of diſſolving ſiliceous earths. In the year 1779, Bergman and Scheele thought that this earth might be a compound of the fluoric acid and water, becauſe of the conſiderable quantity of ſilex depoſited when this acid gas comes in contact with water; but the experiments of Meyer prove that the ſiliceous earth is obtained from the glaſs veſſels which are corroded. This chemiſt took three cylindrical veſſels of tin, in each of which he put an ounce of vitreous ſpar, with three ounces of ſulphuric acid, which, having a ſtronger affinity with lime than the fluoric acid, is ſucceſsfully employed in procuring the latter. To one of theſe mixtures he added an ounce of quartz, in powder; to the ſecond, an ounce of glaſs, in powder; and the third was left without addition. In each of theſe cylinders he ſuſpended a moiſtened ſponge, and expoſed the cloſed veſſels to a gentle heat. Half an hour after, he found a ſiliceous powder depoſited on the ſponge, included over the mixture containing powdered glaſs. Twelve hours after, the mixture containing quartz likewiſe exhibited a ſiliceous incruſtation on its ſponge; but the mixture, which contained neither quartz nor glaſs, preſented no appearance of any depoſition, even at the end of ſeveral days. Bergman himſelf forwarded an account of this experiment to Morveau, informing him at the ſame time, that he renounced his former opinion reſpecting the formation of ſiliceous earth by the union of fluoric acid gas and water. The precipitation, therefore, depends on the ſiliceous earth diſſolved in the fluoric acid gas; and the acid is not in a ſtate of purity till the earth has been precipitated by water and the alkalis.

The fluoric acid and its gas unite with clay, and form a ſweetiſh neutral ſalt, *aluminous fluat* *, which eaſily takes the conſiſtence of a thick jelly.

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* According to the methodical nomenclature we have propoſed, the term *fluorat* ſhould have been uſed, but we have abridged it, as we ſhall the neutral combinations of the ſulphuric acid, which are termed *ſulphats*, inſtead of *ſulphurats*.

It combines with barytes: The ſalt reſulting from this combination, which we diſtinguiſh by the name of barytic fluat, is of a pulverulent form.

The fluoric acid forms a cryſtallizable ſalt with magneſia, magneſian fluat.

It precipitates lime-water, forming immediately calcareous fluat.

It likewiſe combines with potaſh, and conſtitutes fluat of potaſh. With ſoda it forms fluat of ſoda. Laſtly, With ammoniac it forms a ſalt, which we diſtinguiſh by the name of ammoniacal fluat[d].

The foregoing ſhort account of theſe ſaline combinations prove that the fluoric acid differs greatly from the muriatic acid; and this proof is ſtill further confirmed by the order of its affinities with the ſeveral baſes. Bergman obſerves, that the fluoric acid united to potaſh is ſeparated by lime-water; from the ſolution, fluat of lime is ſeen to precipitate. The ſame appearance is obſerved when lime-water is added to the ſolution of fluat of barytes. This philoſopher arranges its affinities in the following order: Lime, barytes, magneſia, potaſh, ſoda, ammoniac; but he obſerves that a greater number of experiments are required to give the neceſſary degree of accuracy to this arrangement.

The fluoric acid has not yet been applied to any uſe; but its property of diſſolving ſiliceous earth will probably render it of great uſe in the arts and chemical operations. M. de Puymaurin has already employed it with ſucceſs in engraving upon glaſs; and has created a new art, which may one day become highly uſeful[e].

Species IV. Nitric Acid[a].

The fluid called ſpirit of nitre in chemical laboratories is a combination of this acid with water. This liquid acid, when very pure, is white; but a very ſmall change cauſes it to become yellow or red, and to exhale fumes of the ſame colour in great abundance. Its cauſticity is ſuch, that it immediately burns and deſtroys the organization of the ſkin and muſcles: It reddens and entirely deſtroys the colour of ſyrup of violets[b].

Expoſed to the rays of the ſun, it becomes of a deeper colour, and more volatile, according to Scheele, which ſhows that it is acted upon by light. This coloration is accompanied with a diſengagement of vital air. Heat volatilizes the acid of nitre, and ſeparates the coloured part in the form of red vapours [c].

The red acid unites with great violence to water, which becomes at firſt green, and afterwards blue [d]. Much heat is given out in this combination. When united to a conſiderable quantity of water, it is called aquafortis [e].

The white and red acids of nitre were formerly conſidered as one and the ſame acid, differing only in the degree of concentration; and that which had the moſt colour was conſidered as the moſt concentrated: But the nature of this ſaline ſubſtance being at preſent much better underſtood, it is admitted that it may exiſt in two different ſtates. In the one, the acid of nitre is colourleſs, more ponderous, leſs volatile, and emits only a white fume; in the other, it is tinged from yellow to a brown red, being lighter, more volatile, and continually emitting red vapours, more or leſs abundant, accordingly as its temperature is higher. Bergman diſtinguiſhes theſe two ſtates of the acid of nitre by the names of dephlogiſticated and phlogiſticated nitrous acid. We call the white or colourleſs acid the *nitric* acid, and that which is coloured we call the *nitrous* acid. We ſhall hereafter explain the cauſe of theſe differences. It will be ſufficient in this place to obſerve, that if the coloured and fuming nitrous acid be diſtilled in a glaſs retort, the red part comes over firſt in vapours, and the acid which remains in the retort becomes white and colourleſs. The deeper the colour of the nitrous acid, the larger will be the quantity of vapours, and the leſs the quantity of clear acid remaining in the retort; and, on the contrary, if a nitrous acid, of a pale red, be ſubmitted to the ſame proceſs, the quantity of vapour is very inconſiderable, and the clear acid which remains is in much greater quantity than in the former caſe. This experiment proves that the deep coloured acid is more volatile than the paler ſort; and that as all coloured ſpirit of nitre is compoſed of theſe two acids in different proportions, they may be obtained ſeparate by diſtillation. In this operation, a certain quantity of vital air is always diſengaged, which may be collected by adapting a pneumatic apparatus to the receiver. It muſt be obſerved, that the red heat of the veſſels ſeparates ſome red vapours from the paleſt nitric acid, and changes the colour of the acid itſelf, which becomes reddiſh. But this change produced by mere heat diſappears when the acid grows cold, and the vapour which had ariſen is again diſſolved in the liquor. The ſame thing happens when water is added to highly coloured nitrous acid: The heat which is produced diſengages the red acid into the atmoſphere, and the portion of this weakened acid which remains in the veſſel is wholly nitric acid. When heat, aſſiſted by light, produces this change in the nitric acid, there is a diſengagement of a certain quantity of vital air or oxygenous gas, proportioned to the nitrous gas which is formed. It is in conſequence of the attraction which exiſts between light, caloric, and oxygen, that this decompoſition of the nitric acid, and its change into nitrous acid, take place. The effect of the red heat of our veſſels imitates that of the ſolar rays.

Nitric acid has no action on ſiliceous earth. It unites with alumine, barytes, magneſia, lime, and the three alkalis, with which it forms the nitrats of theſe ſubſtances. Theſe ſalts ſhall all be examined afterwards. The ſalts formed by the union of the ſame baſes with nitrous acid differ a little from the former, and in our methodical nomenclature are termed *nitrites*.

The nitric acid unites with the carbonic acid, which it abſorbs in a conſiderable proportion. The mutual action of theſe two bodies is not well known.

The nitric acid combines very readily with the muriatic acid. The alchemiſts gave the name of *aqua regia* to this compound, becauſe they uſed it to diſſolve gold, the king of the metals. In future we ſhall call it *nitro-muriatic acid*. It muſt always have appeared ſingular that two acids, neither of which ſingly has any action on gold, ſhould become capable of diſſolving it when united. The alchemiſts, happy in having diſcovered a ſolvent for this precious metal, did not trouble themſelves about the cauſe of the phenomenon. It is but a few years ſince two Swediſh chemiſts, Scheele and Bergman, attempted to diſcover the change which the admixture of theſe two acids produces in each. Scheele, as we have already obſerved, perceived that the yellow vapour produced when the muriatic acid is diſtilled from the calx or oxyd of manganeſe has the ſame ſmell as aqua regia; that it deſtroys the blue colours of vegetables; and that its action on metals is very ſtrong, eſpecially on gold, which it perfectly diſſolves, like the nitro-muriatic acid. He thinks that theſe new properties ariſe from its being deprived of phlogiſton by the oxyd of manganeſe, and that conſequently it has a ſtrong tendency to ſeize that principle from other bodies, and therefore acts powerfully on combuſtible bodies. From theſe facts and ſuppoſitions he gave it the name of *dephlogiſticated marine acid.* We muſt here obſerve this explanation is abſolutely contrary to the theory of Stahl, which Scheele appears to have adopted, ſince the muriatic acid, by the loſs of its phlogiſton, acquires new properties, which that great man attributed to the preſence of the inflammable principle, ſuch as volatility, a ſtrong odour, and a power of acting on combuſtible bodies. We apprehend, moreover, that all theſe phenomena are much more naturally explained by the new theory, as we ſhall preſently ſhow.

Bergman thinks that the nitric acid ſeizes the phlogiſton of the muriatic acid, and becomes partly diſſipated in the form of vapour, and that the marine acid is converted into the ſame ſtate as it poſſeſſes when diſtilled from the oxyd of mangaueſe. The nitro-muriatic acid, therefore, diſſolves gold by virtue of the dephlogiſticated marine acid it contains; hence it happens that the acid mixture is often nothing more than marine acid. Such is the opinion of the celebrated chemiſt of Upſal. The following theory, however, appears to agree better with the facts. When nitric acid is poured upon muriatic acid, the two liquors grow hot, and deeper coloured; an efferveſcence is produced, attended with a mixed ſmell, leſs penetrating than that of muriatic acid, but perfectly reſembling this acid diſtilled from oxyd of manganeſe. Berthollet has diſcovered that oxygenated muriatic acid is diſengaged during this ſtrong action of the two acids. Muriatic acid, therefore, takes from the nitric acid part of the oxygen it contains, and is diſſipated in the form of oxygenated muriatic acid gas. A portion of this acid remains charged with oxygen and nitrous gas, and this mixture conſtitutes aqua regia. Hence it may be eaſily conceived why a very ſmall quantity of nitric acid is required to give the muriatic acid the characters of aqua regia, and why the ſalt of gold affords by diſtillation nothing but the muriatic acid, as likewiſe happens with nitro-muriatic acid diſtilled alone. But it muſt be obſerved, that as a much greater quantity of nitric acid than is neceſſary is commonly uſed to ſaturate the muriatic acid with oxygen, the nitro-muriatic acid, aqua regia, contains theſe two acids, which act each according to its peculiar nature, and form various compounds with bodies expoſed to their action. It is therefore a deſideratum to aſcertain what quantity of nitric acid is required to ſaturate a given quantity of muriatic acid with oxygen, and to convert it into nitro-muriatic acid, without its containing any portion of aquafortis, which would only tend to alter its properties, and render its effects uncertain. Hence it is neceſſary, in the recording of nice chemical operations, to point out the reſpective quantities of the acids made uſe of in compounding the aqua regia employed[g].

The ſpecific gravity of this mixed acid is leſs than that of either of the two which compoſe it; its ſmell is peculiar; its colour citron, verging towards orange: its action on various ſubſtances diſtinguiſhes it from every other acid. Light diſengages the oxygen gas or vital air; heat ſeparates the oxygenated muriatic acid. Aqua regia combines with water in all proportions, at the ſame time producing heat: it diſſolves alumine very ſlowly, and unites with barytes, magneſia, lime, and the different alkalis, producing mixed ſaline combinations, which either cryſtallize ſeparately or together, according to their ſolubility. Aqua regia is much uſed in chemiſtry, eſpecially in the art of aſſaying, as we ſhall have occaſion to obſerve more largely, when we come to ſpeak of metallic ſubſtances.

The intimate nature and compoſition of the nitric acid has been greatly attended to by chemiſts ſince the earlier diſcoveries of Dr. Prieſtley. The opinion of ſuch as think the formation of this acid may be attributed to the ſulphuric, and who regard it as a modification of this laſt, has been ſhown to be founded on fallacious experiments; and it was ſoon found to be compoſed of peculiar principles, in conſequence of the following obſervations.

It has long ſince been obſerved that the nitric acid acts ſtrongly on combuſtible bodies, eſpecially metallic ſubſtances; a large quantity of red vapours exhaling at the ſame time into the atmoſphere, and the acid in ſome caſes being entirely diſſipated in that form. The combuſtible body expoſed to its action is quickly converted into the ſtate of a body which has ſuffered oxydation or combuſtion. And this proceſs is in ſome caſes carried on ſo rapidly, as to cauſe ſudden inflammation of the combuſtible bodies, ſuch as oils, coal, ſulphur, phoſphorus, and certain metals. Stahl attributed this effect to the rapidity with which the acid combined with phlogiſton; but this theory is inſufficient.

Dr. Prieſtley having received, under a glaſs veſſel filled with water, the vapour which is diſengaged during the action of the nitric acid upon iron, obſerved, that inſtead of a red vaporous fluid, a tranſparent and colourleſs gas, reſembling air, is obtained, which he diſtinguiſhed by the name of *nitrous gas*.

This gas has all the external characters of air, but differs in a great number of its chemical properties: its ſpecific gravity is ſomewhat leſs; it is incapable of maintaining either combuſtion or reſpiration; is ſtrongly antiſeptic; has no ſenſible taſte; and does not immediately produce any change in ſyrup of violets. Nitrous gas is not ſenſibly changed by the action of light; heat dilates it; vital air readily combines with it, and converts it into nitrous acid; atmoſpheric air produces the ſame effect, but with leſs intenſity. This combination exhibits many important phenomena. As ſoon as the air comes in contact with the nitrous gas, theſe two colourleſs fluids become red, like the nitrous acid; a conſiderable degree of heat is excited: the water riſes in the receiver, and abſorbs the red vapours, which convert it into a weak aquafortis. The purer the air, the more rapid and evident are theſe phenomena, and a leſs quantity is required to convert a given quantity of nitrous gas into nitrous acid. Lavoiſier found that ſixteen parts of atmoſpheric air are required to ſaturate ſeven parts and one-third of nitrous gas, while four parts of vital air are ſufficient to ſaturate completely the ſame quantity of gas. This remarkable phenomenon perfectly reſembles combuſtion, as Macquer thinks. In fact, it is accompanied with heat, abſorption of air, and the production of ſaline matter; and the deep red colour with which it is accompanied may be conſidered as a kind of flame.

The effects of air in this artificial recompoſition of nitrous acid being different according to the purity of the air made uſe of, Dr. Prieſtley applied nitrous gas, as a teſt to diſtinguiſh the quantity of vital air contained in any given portion of elaſtic fluid, by taking, as the two extremes, the moſt impure gas, which is not changed at all by nitrous gas (as, for example, carbonic acid), and vital air, which is changed the moſt. This proof conſiſts in employing known quantities of the two gaſes, and obſerving the effect, or the quantity neceſſary for the complete ſaturation of each. The leſs the quantity of any kind of air which is required to ſaturate nitrous gas, the more pure or reſpirable that air is; and, on the contrary, the larger the quantity required for that purpoſe, the leſs is its purity.

Many philoſophers have endeavoured to contrive methods of performing this experiment with the greateſt preciſion. The Abbé Fontana has ſucceeded the beſt in his attempts; he has contrived an eudiometer, which is accurately deſcribed by Ingenhouſz in his Inquiries concerning Vegetables. With this inſtrument the purity of air may be eſtimated to an extreme degree of accuracy; but a degree of attention and experience is required in its uſe, without which it is very likely to be productive of error, as the author himſelf obſerves.

It is of great conſequence to be obſerved, with regard to theſe experiments, uſeful and ingenious as they are, that they have not been attended with near the advantage to medicine, by determining the ſalubrity of the air, which was at firſt expected. They indicate merely the quantity of reſpirable air contained in the ſpecimen under examination, but teach us nothing concerning the noxious qualities of this fluid with reſpect to the other animal functions; as, for example, its actions on the ſtomach, ſkin, and in particular the nerves, which produce effects well known to phyſicians, and which follow in conſequence of almoſt every alteration the air is ſuſceptible of [h].

Chemiſts are not yet agreed in their opinions reſpecting the cauſe of the production of nitrous acid by the mixture of nitrous gas and vital air. Dr. Prieſtley, to whom we are indebted for this diſcovery, thinks that nitrous gas conſiſts of the nitrous acid loaded with phlogiſton; and that pure air, having a ſtronger affinity for this laſt ſubſtance, takes it from the acid, which it leaves at liberty: but this theory is far from being ſufficient to explain the phenomenon, becauſe there is ſcarcely any reſidue when the experiment is well made, and becauſe the nitrous acid formed in this operation weighs much more than the nitrous gas made uſe of. Lavoiſier imagined that this property of recompoſing nitrous acid by the addition of pure air is ſufficient to ſhow the compoſition of the acid itſelf. By combining two ounces of ſpirit of nitre, of a known ſtrength, with mercury, which is a combuſtible body, he obtained 196 cubic inches of nitrous gas, and 246 inches of vital air. The mercury, after having changed its form during the diſengagement of the firſt gas, was reduced to its metallic ſtate during the diſengagement of the ſecond, and was found to have ſuffered no loſs. From this experiment, performed with great accuracy, he concludes, 1*ſt*, That the mercury having ſuffered no loſs, the elaſtic fluids cannot be attributed to, or be ſaid to have been obtained from, that metal. 2*d*, That they muſt therefore be attributed to a decompoſition of the nitrous acid. 3*d*, That the nitrous acid made uſe of, whoſe ſpecific gravity, compared with diſtilled water, was as 131607 to 100000, appears to be formed of three principles; nitrous gas, vital air, and water, in the following proportions, in the Paris pound, of 9216 grains; nitrous gas, $627\frac{1}{4}$ grains; vital air, $1082\frac{1}{2}$ grains; water, 7506 grains. 4*th*, That nitrous gas conſiſts of the nitrous acid deprived of vital air, or oxygen. 5*th*, That in all the operations wherein nitrous gas is obtained, the nitric acid is decompoſed, and a part of its oxygen abſorbed by the combuſtible body, with which it has a ſtronger affinity than with the nitrous gas.

There is, however, a difficulty attending this opinion. Lavoiſier did not ſucceed in recompoſing all the acid he made uſe of, but loſt at leaſt the half, and the quantity of pure air obtained was much more than neceſſary to ſaturate the whole quantity of nitrous gas. He confeſſes that he cannot account for this circumſtance. Macquer ſuppoſes it to depend on the loſs of phlogiſton or light, which he conſiders as one of the principles, and ſuppoſes to be diſſipated through the pores of the veſſel during its decompoſition, a part of the pure air, which is not diſſipable in the ſame manner, being left behind. We ſhall ſhortly ſee that this is not the true cauſe of the phenomenon.

The portion of gas which remains after the mixture of vital air and nitrous gas formed likewiſe an objection againſt Lavoiſier's theory; and though this reſidue was very inconſiderable in his experiment, ſeven parts and one-third of nitrous gas, with four parts of vital air, having left only the thirty-fourth part of their whole bulk, yet it was embarraſſing to diſcover the reaſon. It is true that Lavoiſier has ſince aſcertained that the reſidue is much ſmaller when the materials are very pure and accurately proportioned to each other; and we ſhall proceed to ſhow that it is poſſible to make a combination of vital air and nitrous gas ſufficiently pure to leave no reſidue.

There is not the ſame difficulty concerning the aeriform reſidue obtained after the combination of 16 parts of atmoſpheric air with $7\frac{1}{3}$ of nitrous gas. This fluid is known to be azotic gas, or atmoſpheric mephitis. It is likewiſe eaſy to conceive, that water, in contact with nitrous gas, may, in proceſs of time, convert it into nitrous acid, by virtue of the air contained in the firſt mentioned fluid.

But in the theory of Lavoiſier, the nature of the nitrous gas remains to be inquired into; and this point has been cleared up by a valuable experiment of Cavendiſh: he introduced into a tube of glaſs, 7 parts of vital air, obtained without the aſſiſtance of nitric acid, and 3 parts of azotic gas, or atmoſpheric mephitis; the electric ſpark being paſſed through this mixture, its bulk was much diminiſhed, and it became changed into nitrous acid. Hence he concludes, that this acid is a combination of 7 parts of vital, and 3 of azotic air; and that when a certain proportion of the firſt of theſe principles is taken away, as happens when metals, &c. are diſſolved, it becomes nitrous gas; conſequently, according to this opinion, the latter fluid muſt conſiſt of azotic gas, with a leſs proportion of vital air than is neceſſary to conſtitute nitrous acid; and that the addition of pure air only is wanting to convert nitrous gas into that acid. Theſe experiments, and the ingenious theory deduced from them, tend greatly to explain the formation of nitric acid, by the putrefaction of animal matters. It is well known, that a large quantity of azotic gas is diſengaged from theſe ſubſtances during the putrefactive proceſs; and the neceſſity of the contact of air, for the production of this acid, is ſufficiently evident, from the conſideration that it is formed by the union of theſe two elaſtic fluids [‡].

Hence it is likewiſe eaſy to aſcertain the difference between the pure, colourleſs acid, and that which is yellow and fuming, called phlogiſticated by the northern chemiſts, or between the nitric and nitrous. The latter exiſts in all caſes, when the proportion of its two component parts is not accurately ſuch as conſtitutes pure nitric acid, namely, 3 parts of azote to 7 of oxygen. But as a great number of circumſtances, and in general every phlogiſticating proceſs, may diminiſh the quantity of oxygen, by abſorbing more or leſs of that fluid, it follows naturally, 1*ſt*, That this acid is very ſubject to alteration, and muſt be more or leſs fuming according to circumſtances. 2*d*, That in proportion to the quantity of oxygen taken away, it may exiſt in many different ſtates from that of the pureſt nitric acid, which contains the largeſt portion of this principle, to that of nitrous gas, which does not contain enough to be truly acid. 3*d*, That if nitrous gas be totally deprived of oxygen, it will be converted into azotic gas, or mephitis. 4*th*, That the attraction between oxygen and azote not being conſiderable, and a great number of combuſtible bodies having a ſtronger affinity with the former, the nitric acid muſt be decompoſed with much facility by ſuch bodies. Theſe four remarkable properties of the acid of nitre ſerve to explain a great number of chemical phenomena. 1*ſt*, We may conceive, that in this acid the azotic gas and vital air are deprived of much caloric; and conſequently, that they are in the ſtate of azote and oxygen. 2*dly*, That when it is decompoſed by a combuſtible body, the nitrous gas, which is diſengaged, does not require ſo much caloric to convert it into the elaſtic form as vital air and azotic gas do. 3*dly*, That theſe two elaſtic fluids cannot combine in their gaſeous ſtate. 4*thly*, That, conſequently, the vital air obtained from nitrous preparations ſtrongly heated, ſuch as red precipitate, the nitrat of lead, common nitre, &c. muſt contain a portion of mephitis, or azotic gas, and that it is this gas which forms the reſidue after the union of vital air and nitrous gas; a reſidue which does not exiſt when vital air is uſed, which has been diſengaged from the leaves of vegetables, or from manganeſe. 5*thly*, That the ſame thing ſometimes happens with the nitrous gas, which may contain a portion of azotic gas or diſengaged mephitis; that this muſt happen when the gas is prepared with bodies which, being very greedy of oxygen, take it almoſt entirely from the nitric acid, ſuch as iron, the oils, &c. 6*thly*, That the nitrous acid which is coloured, and contains an exceſs of nitrous gas, or azote, or the baſe of mephitis, is in a very different ſtate from that whoſe two principles are in a ſtate of ſaturation; and that, by reaſon of their different properties, it is neceſſary to diſtinguiſh them by particular names [k]. We name the pale acid, which is the ſcarceſt and moſt pure, the *nitric* acid, to conform to the other denominations; and its neutral ſalts we call *nitrats*. We give the name of *nitrous* acid to that which is red, and that of *nitrites* to its ſaline combinations. It is true that we ſeldom have occaſion to ſpeak of theſe laſt; for, though the nitrous acid, or that which is red and fuming, is more common than the pale, it ſeldom happens that it remains ſuch in its combination with the alkaline baſes; the exceſs of nitrous gas eſcapes during the combination, and the nitric or pure acid only enters into the compound. We ſhall ſee that theſe ſalts, called nitrites, which contain the acid, with exceſs of nitrous gas, are not formed, except by the action of heat upon the true nitrats.

The affinities of the nitric acid to the alkaline baſes, are the ſame as thoſe of the muriatic acid. They are arranged by Bergman in the following order: barytes, potaſh, ſoda, lime, magneſia, ammoniac and alumine. According to this celebrated chemiſt, the nitrous or phlogiſticated nitrous acid has the ſame elective attractions as the pure acid itſelf. It is ſtronger than the acids before treated of, and diſengages the carbonic, fluoric, and muriatic acids from their baſes.

The nitrous acid is of very extenſive uſe in the arts; under the name of aquafortis, it is more particularly employed to diſſolve mercury, copper and ſilver, by water-gilders, engravers, and in domeſtic and metallurgic operations, &c. In ſurgery it is uſed to deſtroy excreſcences, and ſmall indolent tumours. In pharmacy, it is uſed in many preparations; ſuch as mercurial water, red precipitate, martial alkaline tincture of Stahl, the yellow unguent, &c. &c. We ſhall mention theſe, with ſeveral other uſes, under the different articles to which they belong.

Species V. Sulphuric Acid.

Sulphuric acid, hitherto called the *vitriolic* acid, is a very cauſtic ſaline ſubſtance, which, when concentrated, burns and corrodes the ſkin, reddens the ſyrup of violets without deſtroying its colour, and exhibits a rough ſtyptic taſte when much diluted with water. This acid, in its pure ſtate, has the form of a very tranſparent, oleaginous fluid, twice as heavy as diſtilled water, and without ſmell; it contains the acid united with water, from which it cannot be entirely ſeparated by any known method. It is called vitriolic acid, becauſe it was formerly obtained from martial vitriol by diſtillation. It is now obtained in France and in England by the complete combuſtion of ſulphur, as will be more amply explained in the hiſtory of that combuſtible ſubſtance. Its extraction and nature require, therefore, that, in a methodical and regular nomenclature, it ſhould be called the ſulphuric acid.

When it is well concentrated, it has very improperly been called oil of vitriol, on account of its conſiſtence.

This acid, as ſhall afterwards be ſhown, takes the concrete form, either by expoſure to cold, or by combination with ſeveral elaſtic fluids.

The action of light on the ſulphuric acid is not known. Some chemiſts have affirmed, that oil of vitriol, expoſed in well cloſed veſſels to the rays of the ſun, becomes gradually more and more coloured, and even that ſulphur is formed: this phenomenon is very far from being proved; and it is even probable that it does not take place: for we ſhall hereafter ſhow that the ſulphuric acid cannot be converted into ſulphur, but by the loſs of its pure air or oxygen, and this ſeparation cannot be made in cloſed veſſels.

Stahl conſidered the ſulphuric acid as the moſt univerſally diffuſed, and the principle of all other acids. The firſt of theſe aſſertions, founded on the conſideration that linen cloths, impregnated with potaſh, and expoſed to the air, become charged, in proceſs of time, with ſulphat of potaſh, or the ſalt formed by the union of this with ſulphuric acid, is now ſhown to be falſe; becauſe theſe cloths are not found to contain an atom of ſulphat of potaſh, though they abound with carbonat of potaſh, or the combination of this alkali with carbonic acid. As to the ſecond, it is by no means proved that the other acids owe their origin to that of ſulphur. Modern experiments have ſhown, that each acid has its peculiar principles, different from every other, excepting the baſe of vital air or oxygen, which is common to all.

Sulphuric acid, heated in a retort, becomes more concentrated by the loſs of a part of its water, and is not volatilized but by a ſtrong heat. Coloured ſulphuric acid becomes clear and tranſparent by the action of heat. During this operation, which is called concentration and rectification of the vitriolic acid, a gas of a very penetrating ſmell, which we ſhall hereafter have occaſion to ſpeak of, under the name of ſulphureous acid gas, and which was the cauſe of its colour, is ſeparated. Though this operation appears to render the ſulphuric acid more clear and pure, it muſt be carried ſtill further, if the acid be deſired in a high ſtate of purity. The fact is, that the ordinary method of concentration deprives it only of water and ſulphureous acid gas, without ſeparating the fixed matters by which it may be changed: its complete purification requires that it be diſtilled to dryneſs; changing the recipient as ſoon as the acid in the retort is ſufficiently concentrated by the firſt part of the proceſs: the dry white reſidue, which finally remains in the retort, conſiſts of ſulphat of potaſh, and ſome other ſubſtances taken up by the acid at the time of its original manufacture.

Concentrated ſulphuric acid, expoſed to the air, attracts humidity, and loſes a part of its force and cauſticity; it likewiſe becomes coloured, by means of the combuſtible particles which float in the atmoſphere, and are ſtrongly acted on by this acid: the quantity of moiſture it abſorbs by this expoſure, is nearly double its own weight [a].

The Duc d'Ayen, by a curious ſet of experiments, made during the violent froſt in the month of January 1776, has ſhown, that this acid, highly concentrated, expoſed to cold between 13 and 15 degrees of Reaumur's thermometer, becomes congealed; that when it is diluted with 2 or 3 parts of water, it cannot be frozen; and that, if it be left continually expoſed to the air in its frozen ſtate, it becomes again fluid, though the temperature of the atmoſphere continues as cold, or even becomes colder than before. This laſt phenomenon is produced by the water contained in the atmoſphere, with which the acid unites, and produces an increaſe of temperature ſufficient to counteract and overcome the power of congelation [b].

Sulphuric acid unites to water with phenomena that indicate a ſudden penetration and intimate union. A ſtrong degree of heat, attended with a kind of hiſſing noiſe, is produced, a peculiar ſmell being at the ſame time emitted. The noiſe produced during this union, ariſes from the eſcape of the air contained in the water, which is ſeen to eſcape in the form of ſmall bubbles [c]. The acid, thus diluted with water, loſes much of the intenſity of its taſte, and its fluidity is greater.

It was formerly called ſpirit of vitriol. By evaporating the water of dilution, by means of heat, the acid may be reſtored to the ſtate of concentrated ſulphuric acid.

This acid does not act on ſiliceous earth or quartzoſe ſtones, not even when they have been previouſly diſſolved in alkalis: it combines with alumine, barytes, magneſia, lime, and alkalis, forming ſulphat of alumine, or alum; ſulphat of barytes, or ponderous ſpar; ſulphat of magneſia, or Epſom ſalt; ſulphat of lime, or ſelenite; ſulphat of potaſh, or vitriolated tartar; ſulphat of ſoda, or Glauber's ſalt; and ſulphat of ammoniac, or vitriolic ammoniac. Its elective attractions for theſe baſes have the ſame order as thoſe of the muriatic and nitric acids, but they are ſtronger; this acid being capable of diſengaging either of the others from its baſe.

The action of ſulphuric acid on other acids has not yet been well aſcertained; we only know, 1*ſt*, That it abſorbs a large quantity of the carbonic acid. 2*d*, That it unites ſo eaſily with the muriatic acid, as to produce heat, and the diſengagement of a large quantity of muriatic acid gas in white vapours. Boerhaave affirms, in his chemiſtry, that the muriatic acid renders oil of vitriol concrete, which may perhaps be true of the oxygenated muriatic acid. 3*d*, That the white and pure nitric acid, added to ſulphuric acid, coloured by a combuſtible body, renders it tranſparent, and is exhaled in the form of nitrous gas, on the application of heat to the mixture. 4*th*, That nitrous gas, added to this acid, cauſes it to take a concrete form, as we ſhall more largely ſhow in treating of the decompoſition of nitrat of potaſh by the ſulphat of iron.

The mode of action of the ſulphuric acid on combuſtible bodies greatly elucidates the nature and principles of this acid. Whenever a combuſtible body, as, for example, a metal, or any animal or vegetable ſubſtance, is placed in contact with concentrated ſulphuric acid, it paſſes with a greater or leſs degree of rapidity to the ſtate of bodies which have been burned, and the acid is at the ſame time decompoſed[d].

Bodies containing oil become black when plunged in cold ſulphuric acid, the acid at the ſame time aſſuming firſt a brown, and afterwards a black colour. If an inflammable body in combuſtion, as, for example, red-hot charcoal, be plunged into this acid, it immediately aſſumes a degree of volatility, with a ſulphureous ſmell, emitting at the ſame time a white ſuffocating fume. If the acid be put in contact with a combuſtible body of a more ſimple nature than organic ſubſtances, the changes which follow may be more eaſily perceived and eſtimated, and the principles of the ſulphuric acid may by that means be ſeparated and known. When concentrated ſulphuric acid and mercury are heated together in a retort, whoſe neck is plunged beneath a glaſs veſſel filled with the ſame metallic fluid, a permanent gas, of a ſtrong and penetrating ſmell, ſimilar to that of burning ſulphur, is produced as ſoon as the acid boils.

This aeriform fluid, known by the name of *ſulphureous acid gas*, is ſomewhat heavier than common air; it extinguiſhes flame, deſtroys animal life, reddens and diſcolours ſyrup of violets, unites to water with leſs rapidity than the muriatic acid gas, and, according to Prieſtley, diſſolves chalk, camphor, and iron; it is abſorbed by charcoal, and all very porous bodies. Though it has been conſidered as one of the permanent gaſes, it appears to be capable of condenſation to the liquid ſtate by a great degree of cold. Monge has ſucceeded in rendering it liquid by this proceſs.

The ſulphureous acid is a peculiar modification of the ſulphuric acid, capable of forming with alkalis neutral ſalts, very different from thoſe produced by the combinations of the latter. Stahl, who paid particular attention to theſe important phenomena, imagined that in this combination the phlogiſton of the metal united with the acid, and gave it ſmell, volatility, &c.; but this great chemiſt, not having purſued the experiment to a ſufficient length, was doubtleſs unacquainted with the circumſtance that the ſtrongeſt objections againſt his doctrine may be deduced from theſe facts. Lavoiſier, Bucquet, and myſelf, have ſeverally examined the ſucceſſion of phenomena which take place during the mutual action of mercury and the ſulphuric acid. As ſoon as the mixture becomes white and dry, ſcarcely any ſulphureous acid gas paſſes over; if this ſulphat of mercury be then ſtrongly heated, a ſmall quantity of water is diſengaged, together with gas of a totally different nature from the former. It conſiſts of very pure vital air. In proportion as this air paſſes over, the mercury is reduced to its fluid and metallic ſtate, abſolutely ſimilar to that which it originally poſſeſſed, and is entirely recovered, excepting certain portions, which together do not amount to the eighth part of the quantity made uſe of. Hence it appears, that the mercury not having been at all altered, the two gaſes, which come over, are produced by a decompoſition of the ſulphuric acid itſelf. Sulphureous gas appears to have the ſame relation to this acid as the nitrous gas has to the nitric acid. There is, however, ſome difference in the compoſition of theſe two acids; for it has not been found practicable immediately to reproduce the ſulphuric acid by uniting the two gaſes it affords, though this may be done at pleaſure with the nitrous acid, by combining the nitrous gas and vital air which its analyſis affords. It is probable that the recompoſition of the ſulphuric acid requires a conſiderable ſpace of time, ſince it really takes place when compounds of the ſulphureous acid, with different baſes, are expoſed to the air, and are found at length to contain mere ſulphuric acid. Thus it is that the combination of the ſulphureous acid with the potaſh, commonly known by the name of ſulphureous ſalt of Stahl, or the ſulphite of potaſh, being expoſed to the air, becomes converted into ſulphat of potaſh at the end of a certain ſpace of time. That which here happens ſlowly, takes place very rapidly in the combuſtion of ſulphur, during which this combuſtible body abſorbs the oxygen of the atmoſphere, and becomes more and more acid, until its complete ſaturation [e].

From theſe experiments, it is evident, 1*ſt*, That the ſulphuric acid is a compound of ſulphur and oxygen; 2*d*, That when a combuſtible body is preſented to this acid, which has a ſtronger affinity than vital air or oxygen to ſulphur, it ſeizes the oxygen, and decompoſes the acid; 3*d*, That if the combuſtible matter do not ſeize the whole of the acidifying principle, as is the caſe with moſt metallic ſolutions in ſulphuric acid, the ſubſtance diſengaged is not pure ſulphur, but ſulphureous acid gas; 4*th*, That this gas occupies the middle place between ſulphur and ſulphuric acid, and muſt be conſidered as that acid deprived of a certain quantity of its oxygen, or as ſulphur rendered feebly acid by a portion of oxygen. In order, therefore, to cauſe this gas to become true ſulphur, nothing more is required than to deprive it of this portion of the baſe of vital air; an event which happens towards the end of metallic ſolutions by the ſulphuric acid, when theſe ſolutions are evaporated and ſtrongly heated. It may likewiſe be readily underſtood in what manner the ſulphureous acid becomes gradually converted into ſulphuric acid, by abſorbing the oxygen or vital air contained in the atmoſphere [f].

Sulphureous acid gas is capable of uniting ſomewhat intimately with the ſulphuric acid, to which it gives the property of emitting thick white vapours. Meyer, in his Chemical Eſſays on Quicklime, ſpeaks of a *ſmoking oil of vitriol*, prepared at Narthauſen in Saxony, by the diſtillation of *common vitriol*. This chemiſt, after Chriſtian Bernhard, a German chemiſt, mentions a concrete and fuming acid-ſalt, obtained from this acid by diſtillation. Having had an opportunity of procuring a few pounds of this Saxon ſulphuric acid, I obſerved the properties mentioned by Meyer; and, by a gentle heat, I obtained a concrete fuming volatile ſalt, in deliqueſcent cryſtals, of two forms, according to the deſcription of Chriſtian Bernhard. A number of experiments which I have deſcribed, in a memoir read to the Royal Academy of Sciences in 1785, have convinced me, 1*ſt*, That the property of fuming and affording a concrete volatile ſalt ariſes from the ſulphureous gas contained in a large proportion in the black ſulphuric acid of Narthauſen; 2*d*, That in proportion as it loſes this gas by expoſure to air, it ceaſes to emit fumes, and affords no more concrete ſalt; 3*d*, That water diſengages this gas, and deprives the Saxon ſulphuric acid of its fuming property, &c.; 4*th*, and *laſtly*, That this concrete and very fuming acid ſalt obtained by diſtillation is a ſaturated combination of ſulphuric acid and ſulphureous gas, which gradually becomes converted into ordinary ſulphuric acid by expoſure to air. Two concrete ſulphuric acids are therefore known; the one formed by the addition of nitrous gas, and the other of ſulphureous acid gas. I do not doubt but that other concrete modifications occaſioned by its combination with other gaſes, as the oxygenated muriatic acid gas, &c. will hereafter be diſcovered.

The ſulphuric acid is uſed in many arts, particularly in hatmaking and in dyeing; it is one of the moſt common and moſt neceſſary ſolvents made uſe of in chemiſtry; it is employed in medicine externally, as a powerful cauſtic, and internally, when diluted with water, ſo as to be ſcarce ſenſibly acid, as a refreſhing, cooling, and antiſeptic medicine.

The ſulphureous acid is employed in dyeing; it is uſed to whiten ſilks, to take out ſpots occaſioned by vegetable juices, &c. As theſe two acids are combinations of ſulphur and oxygen in different proportions, their names ought to have an analogy with their nature; thoſe of *ſulphuric* and *ſulphureous* acid appeared to me to be well adapted: the termination of this laſt word expreſſes the exceſs of the combuſtible baſe, as in the other acids.

Species VI. Boracic Acid.

The labours of a great number of chemiſts have ſhown that borax is a neutral ſalt, formed by the combination of a peculiar acid with an exceſs of ſoda. This acid was called *ſedative ſalt* by its diſcoverer, Homberg. It has ſince been named the acid of borax; we prefer the name of the boracic acid, in order to give this word the termination of all the other acids.

Many chemiſts have ſuppoſed that this acid is an artificial product, formed by the combination of the ſalts made uſe of in its manufacture; but ſince Mr. Hoefer, apothecary to the Grand Duke of Tuſcany, has diſcovered that the waters of ſeveral lakes in that country contain it in a ſtate of great purity, it cannot be doubted but that it is a peculiar acid. The chemiſts of the academy of Dijon have confirmed this diſcovery, by analyſing the waters of Monterotondo which were ſent to them, and in which they found ſedative ſalt, as diſcovered by Mr. Hoefer. It is probable that it may hereafter be found in other mineral waters; it ſeems to be produced by the putrefaction of fat ſubſtances.

Boracic acid, whether native, or obtained from borax, by the proceſs to be mentioned under that article, is a concrete ſubſtance, cryſtallized in ſmall white ſcales, exceedingly thin, irregularly cut at their edges, very light, and ſometimes brilliant in a certain degree. Its taſte is feebly, though ſenſibly, acid; it ſlightly reddens the tincture of violets, and alſo that of turnſole, mallows, radiſhes, &c. much more ſenſibly; it is not volatilized by fire, but melts at a conſiderable red heat into a tranſparent glaſs, which, upon expoſure to the air, becomes opake, and covered with a light white powder. This glaſs is the boracic acid unaltered, and recovers its cryſtalline form, by ſolution in water, and ſubſequent cryſtallization.

The boracic acid is not changed by the action of air, whether it be hot or cold, or in a ſtate of humidity or dryneſs.

It is difficultly ſoluble in water, a pound * of this fluid, boiling hot, diſſolving no more than 83 grains, according to the academicians of Dijon; it cryſtallizes by cooling and by evaporation. This ſolution immediately reddens the tincture of turnſole, and changes the colour of ſyrup of violets, though ſlowly. If boracic acid, moiſtened with a little water, be heated in a cucurbit with a head, a part of the acid ſublimes with the water which riſes, but the ſublimation ceaſes as ſoon as the water has all riſen; a circumſtance which proves that this ſalt alone is fixed, as may be ſhown by melting it in a crucible. By ſublimation in this

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* 9216 grains.

manner with water, boracic acid may be obtained very pure in fine brilliant cryſtals, if the operation be well managed. This ſalt is called *ſublimed ſedative ſalt* in pharmacy.

The boracic acid is uſed to fuſe ſiliceous earth, with which it forms clear, and nearly colourleſs glaſſes; by the aſſiſtance of heat, it diſſolves the earth precipitated from the liquor of flints. It unites with barytes, magneſia, lime, and alkalis, and forms with theſe different ſubſtances ſalts, diſtinguiſhed by the general name of Borats, of which there is only one ſpecies which is yet well known.

All theſe properties, and more eſpecially its taſte, the red colour it communicates to vegetable colours, and its neutral combinations with alkalis, ſufficiently indicate its acid nature; but it is known to be the feebleſt of all the acids, ſince it often ſaturates imperfectly its alkaline baſes, and ſince all the other acids, not excepting the carbonic, diſengage it from its combinations.

The action of acids on boracic acid is not well known; it appears to be partly decompoſed by the ſulphuric acid, the latter becoming ſulphureous when diſtilled from this ſalt. As to the nitric and muriatic acids, it is known that they diſſolve it; but their mutual action has not been obſerved with ſufficient accuracy to determine whether any decompoſition takes place.

There have been many different opinions reſpecting the nature and formation of boracic acid. Many chemiſts have thought it to be an intimate combination of ſulphuric acid and vitrifiable earth with a fat ſubſtance. Meſſrs. Bourdelin and Cadet ſuppoſed it to be formed of muriatic acid. The latter imagined that it contains a ſmall proportion of earth of copper, becauſe, like the oxyds of that metal, it gives a green colour to flame. Cartheuſer affirms, that boracic acid, when dried by a gentle heat, emits vapours of muriatic acid; that this dry ſalt being diſſolved, a grey earth remained on the filter; laſtly, that by repeating the deſiccations and ſolutions a great number of times, the ſalt is entirely decompoſed, ſo that it ſeemed to be a modification of muriatic acid fixed by an earth. Meſſrs. Macquer and Poulletier de la Salle have repeated this experiment. They obſerved the diſengagement of a vapour during the calcination of the ſedative ſalt, but they were not ſatisfied that its ſmell was that of muriatic acid. By ſucceſſive deſiccations and ſolutions, they obtained a ſmall quantity of grey earth, which, when combined with muriatic acid, did not form boracic acid, as Cartheuſer had affirmed; ſo that the opinion of this chemiſt is no more proved than the others. Model conſidered this ſalt as a combination of a peculiar alkali with the ſulphuric acid made uſe of in diſengaging it. But the boracic acid being always the ſame ſubſtance, whatever may be the acid employed to diſengage it, this opinion cannot be admitted. Baumé affirms that he has ſucceeded in forming boracic acid, by leaving a mixture of clay and fat to digeſt together for 18 months. Hence he concludes that this ſalt is a combination of the acid of fat with a ſubtle earth, of which it cannot afterwards be deprived. He adds, that vegetable oils afford the ſame ſalt, though more ſlowly. Wiegleb repeated this experiment of Baumé, but no boracic acid was produced.

Chemiſts at preſent conſider boracic acid as a peculiar acid, different from all others; and the order of its affinities with the alkaline baſes tend to ſupport this aſſertion. Bergman arranges them as follows: lime, barytes, magneſia, potaſh, ſoda, ammoniac. As they differ much from the ſalts formed by the other acids hitherto examined, they prove ſtill more evidently that this acid is of a peculiar nature, whoſe principles are not yet known.

The boracic acid was for ſome time employed in medicine on the authority of Homberg, who affirmed it to be ſedative, and even narcotic. He called it ſedative ſalt, or volatile narcotic ſalt of vitriol, becauſe he had obtained it by ſublimation of a mixture of nitre and vitriol; but experience has ſhown that the virtues of this ſalt are not extraordinary, unleſs the doſe given be greater than that formerly uſed, ſuch as a drachm, or even more; it is therefore rejected; and with ſo much the more juſtice, as it is certain that we poſſeſs remedies whoſe action is much more powerful and certain.

It is uſed in many chemical operations as a flux, under which character we ſhall hereafter have occaſion to conſider it.

NOTES ON CHAPTER IV.

[Page 389.]

I. CARBONIC ACID.

[a] Carbonic acid is the *choke-damp* of miners, ſo called from the fatal effects it produces on thoſe who breathe it. The miners are informed of its preſence, by the faintneſs with which their lights burn, or by their total extinction.

[b] Carbonic acid exiſts in great abundance in chalk, limeſtones, marble, calcareous ſpars, &c. forming nearly one-third of theſe ſubſtances.

[c] It is alſo extricated in conſiderable quantity from putrefying animal ſubſtances: but in this caſe it is impure, being always mixed with other gaſeous bodies.

[d] According to Lavoiſier, the ſpecific gravity of carbonic acid is to that of common atmoſpherical air in the proportion of 1.8454 to 1.2308.

[e] By paſſing a ſucceſſion of electric ſparks through carbonic acid gas, Dr. Prieſtley obſerved, that the volume of this gas was ſomewhat increaſed, and that a portion of it became incapable of combining with water. See *Obſervations and Experiments*, Vol. I. p. 112.

Van Marum repeated Dr. Prieſtley's experiments on a more extenſive ſcale, and obtained nearly ſimilar reſults.

Monge found, that in theſe experiments the increaſe of volume aroſe from the decompoſition of the water, which adheres to carbonic acid in ſpite of every means uſed to ſeparate it, and not from any change in the carbonic acid itſelf. The metallic conductors he employed always underwent a ſlight degree of oxydation. After the abſorption of the carbonic acid by alkaline ſolutions, a gaſeous reſidue was left behind, which exploded readily with oxygen gas. See *Mem. de l'Acad.* 1786, p. 430.

[f] Dr. Prieſtley obſerved, that the carbonic acid is diſengaged alſo during the freezing of water; and that when this effect is ſuddenly produced, the ice formed has all the appearance of ſnow.

[g] Cavendiſh paſſed 180 ounce meaſures of atmoſpherical air through an ignited iron tube filled with powder of charcoal; the air was diminiſhed to 162 meaſures, and a gas produced, which was abſorbed by alkaline ſolution.

Dr. Prieſtley expoſed, in a cloſe glaſs veſſel, charcoal in contact with atmoſpheric air to the action of a burning glaſs. The air was diminiſhed one-fifth, and became capable of rendering lime water turbid. *Prieſtley's Experiments and Obſervations*, firſt edition, Vol. I. p. 129.

Scheele placed burning charcoal in a veſſel containing oxygen gas. After cooling, the air was diminiſhed, by the abſorption of lime water, to one-fourth of its original volume. See *Gren's Journ. de Phyſ.* B. II. ſ. 454.

The memoir of Lavoiſier on the formation of carbonic acid is inſerted in the *Mem. de l'Acad.* 1781, p. 448.

[h] Mr. Tennant ſeems to have been the firſt who ſucceeded in directly decompoſing carbonic acid. Into a glaſs tube cloſed at one end, he introduced a ſmall quantity of phoſphorus, and over this ſome powdered marble, or carbonat of

lime. After expoſing this tube for ſome minutes to a red heat, it was obſerved to contain a black powder, which, on examination, was found to conſiſt of charcoal, phoſphat of lime, and a ſubſtance formed by the union of lime and phoſphorus. The charcoal obtained by this experiment did not ſeem to differ in any reſpect from the charcoal of vegetable ſubſtances. See *Phil. Tranſ.* Vol. LXXXI. p. 181.

Dr. Pearſon repeated this experiment, but, inſtead of lime, he employed carbonat of ſoda, deprived completely of the water of its cryſtallization. 800 grains of this ſubſtance were added to 200 grains of tranſparent phoſphorus. The open end of the tube being adapted to a pneumatic apparatus, the other end was placed in a red heat for about 20 minutes. During this time ſome drops of water, together with a mixture of azotic and oxygen gaſes, having the ſmell of phoſphorus, paſſed over into the receiver. In the lower end of the tube there was now found a looſely cohering ſubſtance as black as charcoal, which weighed 428 grains, and above this a grey and white ſubſtance, partly fuſed, and partly in a powdery form, which, with the glaſs adhering to it, weighed 358 grains. 100 grains of the black ſubſtance afforded by ſolution in boiling hot concentrated acetous acid about ſix ounce meaſures of carbonic acid. The quantity of this acid, however, varied a little in different experiments. The ſolution was filtered, and a black reſidue obtained, which, after being waſhed with boiling water, weighed 32,4 grains. This reſidue ſeemed to poſſeſs all the properties of charcoal, ſo that no doubt could remain with regard to the decompoſition of the carbonic acid. 130 grains of phoſphat of lime were obtained by adding muriat of lime to the filtered ſolution. The reſidue from the white ſubſtance prepared in the ſame way, weighed 44 grains, but only a ſmall portion of it ſeemed to be charcoal.

Dr. Pearſon decompoſed alſo, in the ſame way, the carbonic acid united with potaſh, but not that combined with ammoniac. The carbonic acid contained in the carbonat of lime, barytes, magneſia, and alumine, ſeemed alſo to be decompoſed by expoſing theſe ſubſtances, in contact with phoſphorus, to a ſtrong fire, but in much ſmaller quantity than with either of the fixed alkalis. Inſtead of phoſphorus, Dr. Pearſon tried ſulphur; but he was not able with this ſubſtance to effect the decompoſition of the carbonic acid. See *Phil. Tranſ.* Vol. LXXXII. p. 270.

The ſame experiment has been ſince made at Paris by Fourcroy, Vauquelin, Sylveſter, and Brougniart. This decompoſition, according to theſe chemiſts, takes place only in a high temperature; for when the heat is ſlowly applied, the phoſphorus ſublimes, without producing any effect on the carbonic acid. See *Annal. de Chem.* Tom. XII. p. 315.

Profeſſor Götling of Jena, however, affirms, that the decompoſition of the carbonic acid by phoſphorus takes place alſo in the uſual temperature of the atmoſphere, provided theſe ſubſtances be kept a ſufficient length of time in contact with each other. See *Taſſchenbuch für Apotheker*, 1796, ſ. 33.

i The actual decompoſition of carbonic acid during the vegetation of plants, has not yet been proved by any accurate experiments. Thoſe who wiſh to become acquainted with the moſt probable conjectures on this ſubject, may conſult a memoir of Haſſenfratz, beginning page 318 in the 13th Volume of the *Annales de Chemie*, together with the anſwer to this memoir, by Sennebier of Geneva, inſerted in the *Journal de Phyſique* for September 1792.

II. MURIATIC ACID.

[a] THIS acid never exiſts pure in nature, but always in combination with ſome alkali, earth, or metal. See *Kirwan's Mineralogy*, Vol. II. p. 30.

[b] Pelletier aſſerts, that this abſorption takes place by keeping theſe two ſubſtances ſimply in contact with each other. See *Journ. de Phyſ.* 1785. p. 394.

Hermſtadt inverted a glaſs veſſel, containing 64 cubic inches of oxygen gas, over muriatic acid. At the end of 14 days, 7 cubic inches of the gas were abſorbed. The acid, which had riſen in the veſſel, on being afterwards expoſed to heat, gave out 6 cubic inches of oxygenated muriatic acid. See *Grundzüge von Scherer*, ſ. 170.

[c] Muriatic acid gas is abſorbed by ſpirit of wine as readily as by water. This combination diſſolves iron, and continues to be inflammable. Muriatic acid gas is abſorbed alſo by olive oil, oil of turpentine, wax, ſulphur, charcoal, and ether. See *Prieſtley's Exper. and Obſer.* Vol. II. p. 280.

[d] It was this property of muriatic acid gas that led Morveau to propoſe it as an antidote to the putrid miaſma of hoſpitals. See *Encyclopedie Methodique, Article* Chemie, Tom. I. p. 132.

[e] The ſpecific gravity of highly concentrated muriatic acid is to that of water in the proportion of 1.196 to 1000. According to Lavoiſier, a cubic inch of this acid is equal to 6 drachms 14 grains, *French weight*. The ſpecific gravity of muriatic acid gas is to that of atmoſpherical air as 1.750 to 1000.

[f] Dr. Prieſtley obſerved, that hydrogen gas was diſengaged in expoſing iron filings, ſpirit of wine, oil of olives, and of turpentine, charcoal, phoſphorus, wax, and even ſulphur, to the action of muriatic acid gas. The ſame thing happened with dry cork wood, oak, ivory, ether, and camphor. Inflammable gas was alſo diſengaged by paſſing the electric ſpark through muriatic acid gas. See *Experiments and Obſervations*, Vol. II. p. 280.

La Metherie affirms, that filings of iron and zinc are diſſolved in muriatic acid gas; and that, during their ſolution, inflammable gas is diſengaged. According to him, charcoal, ſugar, oil, wax, ſulphur, and phoſphorus, after being placed for ſome time in muriatic acid gas, leave a reſidue of inflammable gas. As this ſubſtance was conſtantly evolved during the action of muriatic acid gas upon quicklime, and as quicklime contains no inflammable gas, La Metherie concludes, that, in his experiments, this gas muſt have been derived from the muriatic acid. See *Eſſai Analytique*, p. 196.

Sennebier relates ſimilar facts, and has given a ſimilar explanation of them in a memoir, inſerted in *Crell's Chemical Journal* for 1785.

Dr. Girtanner has ſince laid claim to the diſcovery of the baſe of the muriatic acid. He enumerates eighteen experiments in his *Angfangsgründe der Antiphlogiſtiſchen Chemie* to prove that this baſe is *hydrogen*. It will be ſufficient to mention the reſults. In experiments 1ſt, 2d, and 3d, tin, biſmuth, and zinc, were, in a high temperature, oxydated and diſſolved in pure muriatic acid. In 4th, wool decompoſed muriatic acid. In 5th, ſulphure of potaſh produced the ſame effect. In 6th, 7th, 8th, 10th, 11th, muriatic acid gas was decompoſed, in a high temperature, by manganeſe, copper, and iron. In 9th, 12th, 13th, 14th, and 15th, alcohol, olive oil, oil of turpentine, and wax, were oxydated by the muriatic acid. In 16th, 17th, and 18th, carbon, phoſphorus, and ſulphur, in a high temperature, were converted into their reſpective acids by expoſure to the action of the muriatic acid gas. In all theſe inſtances, while the oxygen of the muriatic acid, combined with the combuſtible body, hydrogen, the other conſtituent part of that acid was conſtantly diſengaged under an elaſtic form. It is to be regretted, that, in theſe experiments, Dr. Girtanner ſhould have neglected to mention the relative proportions of the ſubſtances upon which he operated with the products he actually obtained. Weight and meaſure are now eſſential to every accurate chemical experiment; nor can any analyſis be conſidered as complete in which they have not been employed. Muriatic acid, in its gaſeous as well as in its liquid ſtate, is known to contain a conſiderable quantity of water. Is it not, therefore probable, that, in the experiments of Prieſtley, La Metherie and Girtanner, this, not the acid, was the ſource from which the hydrogen gas was derived?

But all uncertainty with regard to the decompoſition of the muriatic acid, in theſe experiments, has been completely removed by the very accurate experiments of Van Mons. This chemiſt ſaturated two half ounces of muriatic acid, one with the oxyd of tin, the other with tin in its metallic ſtate. During the ſolution of the oxyd no hydrogen gas was evolved, yet the quantity of muriat of tin from both ſolutions was nearly the ſame. He precipitated the metals by vegetable alkali, and found that the ſame quantity of this ſubſtance was neceſſary to decompoſe the ſalts which had been formed.

He repeated theſe experiments with zinc, and obtained preciſely the ſame reſults. Nothing can ſhow more ſatisfactorily that no portion of the muriatic acid had been decompoſed.

The combuſtion of alcohol did not decompoſe any portion of the muriatic acid, for the ſame quantity of potaſh was neceſſary to ſaturate the acid after as before the experiment.

Van Mons obtained only a very ſmall portion of hydrogen gas by paſſing muriatic acid gas through heated glaſs tubes, containing filings of iron, tin, copper, or zinc.

Carbon, ſulphur, and phoſphorus, diſengage hydrogen from muriatic acid only in a temperature equal to that in which theſe ſubſtances decompoſe water.

He heated in a glaſs tube muriat of magneſia with phoſphorus in the manner of Tennant, but no decompoſition took place, nor was any hydrogen gas evolved. The experiment was made alſo with muriat of lime, and with the ſame want of effect. See *Nachtrage von Scherer*, ſ. 442.

g There are two obſervations of Berthollet's which explain, in the cleareſt manner, the nature of oxygenated muriatic acid; 1ſt, That if mangaueſe, which has been previouſly deprived of its oxygen, be diſtilled with muriatic acid, no oxygenated muriatic acid will be formed; 2dly, That if oxygenated muriatic acid be expoſed to the rays of the ſun, the oxygen will be ſeparated under an elaſtic form. —The acid, during this ſeparation, returns to the ſtate of common muriatic acid. Mere heat, without light, is not ſufficient to produce this effect.

Oxygenated muriatic acid is likewiſe formed by adding muriatic acid to the nitric acid. During their combination, oxygenated muriatic acid gas is diſengaged, and this diſengagement may be prolonged by the application of heat. The liquor which remains is the peculiar acid combination known by the name of *Aqua Regia*. The ſame acid combination will be produced by mixing oxygenated muriatic acid with nitrous gas.

Acetous is converted into acetic acid by expoſure to oxygenated muriatic acid gas.

The action of this acid, either in its liquid or gaſeous ſtate, upon the other acids, has been as yet but little attended to. It has been ſaid to unite with the carbonic without altering in any degree the compoſition of that acid.

The combinations of oxygenated muriatic acid with alkalis, earths, and metals, now form a particular claſs of ſalts. It is ſingular that this acid, in combining with the alkaline carbonats excites no effervefcence. The cauſe of this fact has not yet been ſatisfactorily explained. We are ignorant whether any combination takes place between the two acids, or whether the want of effervefcence may not rather be owing to the gradual diſengagement of the carbonic acid and its ſubſequent union with the water of ſolution. Trommſdorf aſſerts, that the oxygenated muriatic acid has no affinity for magneſia. See *Annal. de Chem.* Tom. XXII. p. 218.

Phoſphorus, in a high temperature, without light, remains unaltered in oxygenated muriatic acid; but, if the light be admitted, the colour of the acid gradually diſappears, while the phoſphorus is changed into phoſphoric acid.

The oxygenated muriatic acid converts ſulphur, in the light, to ſulphureous acid. It produces the ſame change on the ſulphures of the fixed alkalis. During theſe proceſſes, the oxygenated muriatic acid paſſes to the ſtate of common muriatic acid.

In pouring water, ſaturated with ſulphurated hydrogen gas, into oxygenated muriatic acid, Berthollet obſerved, that the properties of this acid were deſtroyed, and that ſulphuric acid was formed. If, on the contrary, a ſmall quantity of oxygenated muriatic acid was added to this water, the mixture became muddy from the precipitation of ſulphur. In the firſt experiment, part of the oxygen of the oxygenated muriatic acid united with the ſulphur to form ſulphuric acid, and part of it with the hydrogen to form water; but, in the ſecond, the oxygen united only with the hydrogen while the ſulphur was precipitated.

Oxygenated muriatic acid thickens oils, and animal fats, and renders them leſs diſpoſed to combine with alkalis. Oil of turpentine, for inſtance, ſeemed to be converted by this acid into a kind of reſin, a change analagous to that which is produced in this oil by its combination with oxygen.

The action of the oxygenated muriatic acid upon metals preſents phenomena extremely curious and important. The oxygen of the acid unites with the metal, and the oxyd produced is afterwards diſſolved by the muriatic acid.

Oxygenated muriatic acid, in the ſtate of gas, exhibits ſome properties different from thoſe which it poſſeſſes in the liquid ſtate.

If a candle be dipped into this gas, it will burn more rapidly than in common atmoſpheric air.

Phoſphorus inflames ſpontaneouſly in this gas. During the combuſtion, the phoſphorus is converted into phoſphoric acid, while the fumes of common muriatic acid are diſengaged.

In Weſtrumb's experiments, ſulphur was changed by this gas into ſulphureous acid, but no inflammation was produced.

With hydrogen gas it unites with detonation. The reſults of this combination are water and muriatic acid.

Phoſphorated hydrogen gas burns in this gas with a flame more lively than in atmoſpherical air, but leſs ſo than in oxygen gas.

Carbon in powder inflames in this gas, and is converted into carbonic acid. The ſame effect is produced upon common coal in a temperature of about 90 of Fahrenheit.

Camphor was converted into an oily ſubſtance by the oxygenated muriatic acid gas, but we are not told whether any camphoric acid was formed.

Alcohol ſmoked, but did not inflame in this gas; the ſmell of the alcohol became very agreeable, though no other ſeemed to be produced.

Metals inflame ſpontaneouſly in oxygenated muriatic acid gas. In making this experiment, the metallic ſubſtances muſt be reduced to the ſtate of a powder, and employed in the proportion of a grain to two cubic inches of gas. During the inflammation the metals are converted into oxyds, while the gas is reduced to the ſtate of muriatic acid.

Mercury is the only metal which does not inflame in this gas, but it loſes its fluidity, and is converted into an oxyd.

The quantity of the light emitted during inflammation, and the colour of the flame vary greatly in the different metals.

It is not only neceſſary, for the ſucceſs of theſe experiments, that the temperature of the oxygenated muriatic acid gas be from 60 to 70 of Fahrenheit, but alſo that the gas itſelf be in a ſtate of purity. It often receives an admixture of azotic and carbonic acid gaſes from the manganeſe with which it is prepared. See *Scheele's Chemical Eſſays*, p. 90.; *Berthollet Mem. de l'Acad.* 1785, p. 276.; *Berthollet Elem. de la Teint.* p. 232.; *Weſtrumb. Annal. de Chem.* Tom. VI. p. 24.; *Prieſtley Exper. and Obſer.* Vol. III. p. 235.; *Fourcroy Annal. de Chem.* Tom. IV. p. 249.; *Berthollet Ann. de Chem.* Tom. XI. p. 3.

Weſtrumb, Giobert, and ſome other chemiſts, in diſtilling muriatic acid with oxyd of manganeſe, have at different times obſerved a ſmall quantity of oil floating on the ſurface of the acid in the receivers. Girtanner attributes the formation of this oil to the combination of the hydrogen, or *baſe* of the muriatic acid with the carbon of the manganeſe. Berthollet, Fourcroy, and Vauquelin, however, agree in ſaying, that this oil is never produced unleſs when fat lutes are uſed to confine the oxygenated muriatic acid. See *Annal. de Chem.* Tom. X. p. 3.

[h] The oxygenated muriatic acid, during its action on vegetable colouring ſubſtances, is reduced to the ſtate of common muriatic acid. See *Fourcroy Ann. de Chem.* Tom. V. p. 80.; *Berthollet Ann. de Chem.* Tom. VI. p. 210.

Several improvements have been made in the method of bleaching firſt introduced by Berthollet. The principal of theſe conſiſt in combining the acid with alkalis or lime. In this ſtate of combination, it has not been found to corrode, or in any way to injure the cloth. This improved proceſs is now employed in ſome of the moſt extenſive bleaching concerns of this country, and muſt undoubtedly be conſidered as one of the moſt valuable donations which modern chemiſtry has yet conferred on the arts. See *Berthollet Annal. de Chem.* Tom. II. p. 151, Tom. VI. p. 204.; *Kerr's Tranſlation of theſe Memoirs*; *Hauſſman Ann. de Chem.* Tom. XI. p. 237.; *Chaptal Mem. de l'Acad.* 1787, p. 611.; *Tennant, Repertory of the Arts.*

III. FLUORIC ACID.

[a] Margraaf, in diſtilling fluor ſpar with ſulphuric acid, ſaw, with aſtoniſhment, that the retort was pierced with numerous holes, and that a portion of the receiver was alſo diſſolved. His reſearches are contained in the *Berlin Memoirs* for 1768.

[b] Spirit of wine imbibes this gas. The ſiliceous earth which the gas holds in ſolution, is not precipitated by this combination, for the ſpirit of wine continues limpid, and is as inflammable as ever.

Fluoric acid gas diſſolves camphor, and is abſorbed by ether and by oils. It has no ſenſible effect on nitrous gas. See *Prieſtley's Exper. and Obſer.* Vol. II. p. 349.

[c] Wiegleb has ſhown the fallacy of this opinion by a very accurate experiment,

He weighed his retort and receiver before and after the diſtillation of this acid, and found, that the loſs which theſe veſſels had ſuſtained, exactly correſponded with the weight of the earth which he obtained. Scheele has alſo given a very ſatisfactory confutation to the hypotheſis of Montet. This chemiſt maintained, that the fluoric was merely ſulphuric acid combined in a peculiar manner with the earth of fluor. But Scheele has found by experiment, that the quantity of ſulphuric acid remaining in the retort in combination with the calcareous earth of the fluor, is always equal, or nearly ſo, to that which he employed in the experiment. See *Scheele's Chemical Eſſays*, p. 1. to p. 67.

d The fluoric acid has no action on gold, ſilver, lead, mercury, tin, antimony, biſmuth, cobalt, nickel, arſenic, and manganeſe, in their reguline ſtate. It diſſolves them, however, in that of oxyds. Iron and zinc diſſolve in this acid; and their ſolution is accompanied by the evolution of hydrogen gas.

IV. NITRIC ACID.

a It would have been more conformable to the principles of the new nomenclature, to have denominated this acid from its baſe, the *azotic* acid.

b The nitric acid gives a yellow colour to the ſkin, to ſilk, and to almoſt all animal ſubſtances. Though this acid deſtroys wool and ſilk, yet linen is little altered by it, unleſs the linen be afterwards expoſed to the action of the air. Scheffer aſſerts, that it may be kept a whole day, without injury, in nitric acid, provided it be waſhed immediately with water on being taken out of the acid. See *Keir's Chemical Dictionary*, p. 94.

c It appears from Mr. Macnab's experiments, made at Hudſon's Bay, that nitric acid may be frozen by expoſure to cold; but its freezing point ſeems to vary according to the ſtate of the acid. It is worthy of remark, that the difficulty in freezing was by no means in proportion to the ſtrength of the acid. See *Phil. Tranſ.* Vol. LXXVIII. p. 166.

d Bergman ſays, that if one fourth of water be added to concentrated nitric acid, it will acquire a green, if an equal quantity, a blue colour; but, if more water be added, the acid will again become colourleſs.

e It continues to give out heat till it has been mixed with three or four times its weight of water. When diluted to this degree, it produces cold by mixing it with ſnow. Mr. Walker found that the cold, produced by a mixture of ſnow and nitric acid, at the temperature of 7° of Fahrenheit, was ſufficient to freeze mercury. See *Phil. Tranſ.* Vol. LXXXV. p. 270. The ſpecific gravity of the moſt concentrated nitric acid is to that of water nearly in the proportion of 19 to 12. In this ſtate it is ſaid to attract moiſture from the atmoſphere.

f The addition likewiſe of any acidifiable ſubſtance to colourleſs nitric acid ſoon gives it a red colour by depriving it of a portion of its oxygen. A bit of cork, for inſtance, produces this effect in a very ſhort ſpace of time. The red ſmoking nitrous acid will become again colourleſs if we occaſionally admit to it atmoſpheric air; or, more quickly ſtill, if we admit oxygen gas.

g The nitro-muriatic acid may likewiſe be formed by diſſolving the muriats of ſoda or ammoniac in nitric acid, or by diſſolving the nitrat of potaſh in muriatic acid.

Dr. Prieſtley procured it by keeping nitrous gas in contact with muriatic acid till about two-thirds of the gas were abſorbed. The acid, by this expoſure, acquired the property of diſſolving gold with great readineſs.

Berthollet remarked, that the nitro-muriatic acid, prepared with nitrous, is weaker than that prepared with nitric acid. See *Mem. de l'Acad.* 1785, p. 276.

h This inſtrument, ſo uſeful to chemiſts, is ſubject to many inaccuracies. Cavendiſh remarks, that there will be a difference in the reſult with the ſame quantities of nitrous gas and atmoſpherical air, according to the manner in which theſe gaſes are mixed together. If they be allowed to remain in contact for ſome time without agitation, the volume of the reſidue will be different from what it would have been had they been agitated immediately on coming into contact. In his experiments, a difference was produced in the reſult by mixing the gaſes (in the ſame proportion) in larger or ſmaller quantities. The reſult of this mixture will alſo be modified by the ſtate of the nitrous gas; the quantity of oxygen contained in it being found to vary according as the body with which it has been prepared has a greater or leſs attraction for oxygen, according to the temperature in which it is formed, the length of time it has been kept, &c.

To avoid theſe ſources of fallacy, chemiſts have had recourſe to other ſubſtances leſs variable in their nature than nitrous gas. Morveau has propoſed to employ the ſulphure of potaſh as a teſt of the quantity of oxygen gas contained in any elaſtic fluid. When the gas is pure it is wholly abſorbed. In making this experiment the ſulphure is to be introduced into a retort, containing the gas to be tried, and the flame of a candle applied, ſo as to heat it a little. The heat, with gentle agitation, greatly promotes the abſorption.

From the tendency which muriat of tin has to abſorb oxygen, Pelletier propoſed this ſubſtance as a teſt to determine the quantity of oxygen gas contained in any elaſtic fluid.

Phoſphorus has alſo been propoſed; but this ſubſtance is liable to ſeveral objections. The heat excited during its combuſtion is often ſuch as to break the veſſels in which the experiment is made, nor can we be at all times certain that the oxygen gas contained in any elaſtic fluid has been entirely conſumed by this ſubſtance. Seguin deſcribes a very ſimple mode of trying the purity of any gas with phoſphorus. It conſiſts in introducing a bit of phoſphorus into a tube 6 or 7 inches in length, filled with, and inverted over mercury. The phoſphorus is to be melted by heat, and the gas to be tried gradually introduced. We judge of the quantity of oxygen which it contains from the quantity of gas conſumed during the experiment. This is the apparatus which Lavoiſier employed to aſcertain the purity of the gaſes on which he operated. For a more minute account of this ſubject, ſee *Prieſtley Exper. and Obſerv.* firſt edition, Vol. III.; *Cavendiſh Phil. Tranſ.* LXXIII. p. 106.; *Lavoiſier Mem. de l'Acad.* 1782, p. 486.; *Seguin Annal. de Chem.* Tom. IX. p. 293.; *Reboul Do. Do.* Tom. XIII. p. 38.; *Pelletier Do. Do.* Tom. XII. p. 240.; *Morveau, Nicholſon's Journal*, Vol. I. p. 268.; *Hutton's Mathematical Dictionary*, Vol. I. p. 449.

i The important experiment of Cavendiſh has ſince been repeated by Van Marum and by Lavoiſier.

Van Marum operated on a mixture of five parts of oxygen gas with three of atmoſpherical air, and continued the experiment till 8 3-4ths cubic inches of gas diſappeared. In a ſecond experiment, 14 cubic inches, and in a third 22, were converted by the electric ſpark into nitric acid.

Lavoiſier obtained nitrous gas only by paſſing the electric ſpark through a mixture of 20 parts by weight of azotic, and 43 of oxygen gas. But when the gaſes were in the proportion of 79 of oxygenous to 20 of azotic, he obtained nitric acid. In a proportion intermediate between theſe extremes, nitrous acid was always produced.

This chemiſt found, that 40 ounces of oxygen gas were neceſſary to convert 66 of nitrous gas into nitric acid; and he remarks, that during the combination these gaſes, only a very ſmall quantity of caloric is evolved.

Hermbſtadt obſerved, that fuming nitrous acid was changed into nitric, by diſtilling it over the oxyd of manganeſe.

Mr. Milner diſcovered another artificial mode of forming nitrous gas, which we have already had occaſion to mention in the note on Ammoniac. It conſiſts in paſſing the vapour of ammoniac through an ignited gun barrel, containing oxyd of manganeſe. The gas which paſſes over is a mixture of nitrous and undecompoſed ammoniacal gas. If atmoſpherical air be admitted to this mixture, the oxygenous part of it is abſorbed, and white clouds of nitrat of ammoniac inſtantly produced. This experiment did not ſucceed with the oxyd of lead. With calcined ſulphat of ſoda, however, ſome ounces of nitrous gas were obtained. Mr. Milner remarks, that nitrous gas, and not nitrous acid, was procured, becauſe nitrous acid is decompoſed in the temperature neceſſary for the ſucceſs of this experiment.

The ſame combination has been produced, but in a different manner, by Fourcroy. He diſſolved ſulphat of mercury in ammoniac, and obtained from the ſolution nitrat of ammoniac, nitrat of mercury, and a portion of a triple ſalt, reſulting from the combination of ſulphuric acid, ammoniac, and mercury. He found alſo, that by diſſolving oxygenated muriat of mercury in ammoniac that a triple ſalt is formed, conſiſting of nitric acid, ammoniac, and mercury. In theſe experiments, a part of the azote of the ammoniac unites with the oxygen to form nitric acid, while the hydrogen unites with another portion of oxygen to form water. Chemiſtry now poſſeſſing, adds Fourcroy, the means of forming ammoniac, by decompoſing the nitric acid with ſubſtances which have a ſtrong affinity for oxygen, and of forming nitric acid, by decompoſing ammoniac with ſubſtances which are highly oxygenated.

In pouring concentrated ſulphuric acid on liquid Pruſſiat of ſoda, Vauquelin obſerved that an elaſtic fluid was diſengaged, which had the ſmell and colour of nitrous gas. It produced the ſame apparent effect alſo when mixed with atmoſpherical air.

The facts which prove the decompoſition of the nitric acid are not leſs numerous.

Scheele obſerved, that if colourleſs nitric acid be expoſed for ſome days to the ſolar light, it becomes of a red colour, while a portion of its oxygen is diſengaged under a gaſeous form. Dr. Prieſtley found, that theſe changes could be effected in a much ſhorter period by uſing a burning glaſs.

If the vapour of nitric acid be made to enter into an ignited earthen tube, oxygen gas, with an admixture of azotic, will paſs over into the receiver. Nitrous gas ſubjected to the ſame proceſs does not undergo any change.

If nitrat of potaſh be expoſed to heat in cloſe veſſels, its acid will be decompoſed. A very copious extrication of oxygen gas takes place, which is mixed, towards the latter ſtage of the proceſs, with azotic gas. If the heat be ſufficiently intenſe and long continued, pure potaſh will be left in the retort. The weight of the two gaſes when collected, will be found to correſpond very exactly with the weight of the acid which has been decompoſed.

Dr. Prieſtley obtained oxygen gas by paſſing the electric ſpark through nitric acid; but, in ſome ſituations, a change of a contrary nature takes place. If nitrous gas be expoſed to electric ſucculſions, nitrous, or nitric acid, is formed, and azotic gas diſengaged. If the experiment be made over water, the water acquires acid properties; if over a ſolution of potaſh, nitrat of potaſh will be formed. In all theſe caſes the nitrous gas is reduced to about one-third of its original volume, and is after the experiment found to conſiſt chiefly of azotic gas. When mercury, however, is uſed to confine the nitrous gas, the gas is decompoſed, and the mercury converted into an oxyd.

The combinations, as they have been termed, of this acid with inflammable bodies, exhibit ſome of the moſt ſtriking and curious phenomena in chemiſtry. In all of theſe, this acid is conſtantly decompoſed. We are acquainted with only four ſimple bodies which do not produce this effect. Theſe are, the diamond, gold, ſilver, and platina.

If charcoal, deprived by heat of the air which it uſually contains be put into nitric acid, a mixture of carbonic acid and nitrous gas will be evolved. Lavoiſier obtained the ſame reſult, by conducting heated nitric acid over charcoal. If nitrat of potaſh be mixed with carbon, and ſubjected to the proceſs of diſtillation, carbonic and azotic gaſes are diſengaged The ſame change happens when theſe two ſubſtances are expoſed to the naked fire. In all theſe inſtances the oxygen of the nitric acid quits its baſe, azote, to unite with the carbon, with which it forms carbonic acid.

Scheele found, that phoſphorus, by digeſtion in nitric acid, was converted into the phoſphoric acid. Lavoiſier prepared a great quantity of the phoſphoric acid by this proceſs, and thinks that it may be employed with advantage when we wiſh to procure this acid in a ſtate of purity. Chaptal made a variety of experiments with regard to the action of the nitric acid on phoſphorus. If a drachm of ſmoking concentrated acid be poured on two drachms of phoſphorus, a ſpontaneous inflammation takes place. If a larger quantity of acid be uſed, the phenomena are ſomewhat different. Small air bubbles appear on the ſurface of the phoſphorus, an effervеſcence takes place, and nitrous gas is diſengaged. He remarked that the phoſphorus burns only when it comes into contact with atmoſpherical air; for by fixing it down to the bottom of the veſſel containing the nitric acid, it was diſſolved without any inflammation. In theſe experiments, it ſeems almoſt ſuperfluous to remark, that the oxygen of the nitric acid unites with the phoſphorus to form phoſphoric acid.

Chaptal obtained 4 ounces of concentrated ſulphuric acid, by diſtilling 48 ounces of pure nitric acid over 2 ounces of ſulphur. The ſulphures of the fixed alkalis decompoſe nitrous gas, by depriving it of its oxygen. The ſulphur is by this proceſs converted into ſulphuric acid, which forms a ſulphat of the alkali.

Pyrophorus inflames in nitrous gas. This is diminiſhed by the inflammation about one half in volume, while it is converted into azotic gas.

Hydrogen explodes with nitrous gas fully better than with atmoſpherical air.

Metallic bodies decompoſe the nitric acid, while the oxygen of the acid unites with the metal, and forms an oxyd. The other conſtituent part of the acid is diſengaged in the form of nitrous or of azotic gas.

Milner found, that by paſſing the vapour of nitric acid through ignited iron filings, pure azotic gas paſſed over into the receiver. The reſult was the ſame with copper. If the vapours were made to paſs over too quickly, the azotic always contained an admixture of nitrous gas. Dr. Prieſtley expoſed iron filings in nitrous gas to the action of a burning glaſs. The gas was decompoſed, and the iron converted into an oxyd. Van Marum remarked, that tin, lead, iron, and mercury were all oxydated, by taking the electric ſpark in contact with them in nitrous gas. Iron long expoſed to nitrous gas gives out ammoniac. The azote in this inſtance can only be derived from the nitrous gas, the hydrogen from the decompoſition of water. This decompoſition is more quickly effected, by putting bits of iron in a ſolution of copper in the nitric acid. Morozzo converted mercury into an oxyd, by ſimple agitation in nitrous gas.

Oils, as we ſhall afterwards have occaſion to remark, poſſeſs the property of decompoſing nitric acid. Some of them do this with a rapidity, heat, and flame which is truly aſtoniſhing. Moſt of the eſſential, and even ſome of the fixed oils, aſſume an orange colour, and thick reſinous conſiſtence, from the action of nitrous gas. The reſidue, after theſe changes, is ſaid to be azotic gas.

We ſhall afterwards have occaſion to remark, that many vegetable ſubſtances are converted into acids by decompoſing the nitric acid. Similar changes are produced by its action on animal ſubſtances. But theſe will require a more minute conſideration than can with propriety be given to them in this place. See *Caven-diſh Phil. Tranſ.* Vol. LXXIV. p. 119. Vol. LXXV. p. 372. Vol. LXXVIII. p. 261.; *Van Marum Journ. de Phyſ.* Juillet 1787, p. 348.; *Lavoiſier Mem. de l'Acad.* 1776, p 671.; *Prieſtley Exper. and Obſer.* Vol. I. p. 328. Vol. II. p. 2. Vol. III. p. 1.; *Chaptal Mem. de l'Acad* 1779, p. 454.; *Lavoiſier Do. Do.* 1778, p. 535.; *Lavoiſier Do. Do.* 1780, p. 349.; *Berthollet Do. Do.* 1781. p. 21, 228, 234.; *Milner Phil. Tranſ.* Vol. LXXIX. p. 300.; *Fourcroy Annal. de Chem.* Tom. VI. p. 293.

[k] There is ſtill another combination of azote with oxygen which deſerves to be mentioned. It was firſt diſcovered by Dr. Prieſtley; but its nature and properties have been ſince more minutely inveſtigated by a ſociety of Dutch chemiſts.

A candle burns in this gas with an increaſed and lively flame. It is diſtinguiſhed from nitrous gas by producing no viſible change on atmoſpherical air. Nitrous gas has no action on this ſubſtance; neither does it ſuffer any change by mixing it with oxygenated muriatic acid gas. Dr. Prieſtley ſays, it is lighter than atmoſpherical air. Water abſorbs about one-half its own bulk of this gas, but does not from the abſorption acquire any marks of acidity. It retains all its properties unchanged, after being again expelled from the water by heat. This gas has no apparent action on any of the alkalis. The addition of a little ammoniac to water, prevents it from being abſorbed by that liquid. It is very noxious to animals. If lighted phoſphorus, charcoal, or ſulphur, be introduced into this gas, they are inſtantly extinguiſhed, without any previous increaſe of flame. It explodes, however, violently with hydrogen gas. It ſeems to be decompoſed by expoſure to a high temperature; for after being ſubjected to this, its volume is conſiderably diminiſhed by mixing it with nitrous gas. Similar effects are produced on it by frequent ſuccuſſions of the electric ſpark.

Dr. Prieſtley, from ſome theoretical opinion which he entertained with regard to the nature of this gas, gave to it the name of *dephlogiſticated nitrous air*. The Dutch chemiſts, in conformity with the principles of the new nomenclature, call it the *gaſeous oxyd of azote*. The propriety of the latter appellation will appear, by conſidering ſome of the circumſtances in which it is formed.

If nitrous gas be kept for ſome time in contact with iron filings which have been moiſtened with water, it ſuffers a conſiderable diminution of volume, and is converted into the gaſeous oxyd of azote.

Nitrous gas placed over ſolutions of the ſulphures of potaſh and ſoda, affords the ſame gas. During this converſion, the nitrous gas is diminiſhed about two-thirds in volume.

Muriat of tin in contact with nitrous gas changes it into the gaſeous oxyd of azote, in conſequence of the great affinity which this ſubſtance has for oxygen.

The gaſeous oxyd of azote may likewiſe be obtained, by keeping nitrous gas in contact with a weak ſolution of tin in ammoniac. The copper in this ſolution is known to poſſeſs the property of attracting oxygen from the atmoſphere.

This gas is procured, though in a leſs pure ſtate, by paſſing nitrous gas through melted ſulphur, which is kept in a red heat.

If phoſphorated hydrogen gas be mixed with nitrous gas, the volume of the two gaſes will be diminiſhed in the courſe of an hour or two, and a candle will then burn in the reſidue, as in the gaſeous oxyd of azote.

This gas is likewiſe obtained in circumſtances ſimilar to thoſe in which nitrous gas is obtained; and there is reaſon to believe, that in many inſtances theſe two fluids have been miſtaken for each other. The Dutch chemiſts found, that in diſſolving iron filings in a mixture of diluted ſulphuric and nitric acids, hydrogen gas was firſt evolved, then the gaſeous oxyd of azote, and afterwards nitrous gas.

The ſolution of iron, zinc, and tin in diluted nitric acid, is accompanied with the diſengagement of the gaſeous oxyd of azote. If the acid be employed in the concentrated ſtate, nitrous gas alone will be produced.

The gaſeous oxyd of azote is formed during the ſolution of tin in diluted nitro-muriatic acid, but in leſs quantity than when nitric acid is employed.

This gas is produced alſo in great abundance, by heating nitrat of ammoniac in cloſe veſſels with three times its volume of ſand. The ſand is uſed to prevent too rapid diſengagement, which would otherwiſe take place.

It appears from theſe experiments, that the gaſeous oxyd of azote is uniformly produced, when ſubſtances having a ſtrong affinity for oxygen are brought into contact with nitric acid, or with nitrous gas; and conſequently, that it differs from theſe ſubſtances in containing a leſs quantity of oxygen. The Dutch chemiſts have endeavoured to aſcertain the proportion of oxygen in this ſubſtance, by the quantity of hydrogen which it is able to conſume. In a 100 parts of this gas, according to their eſtimate, the proportion of the oxygen was to that of the azote as 37 is to 63. It ſeems only neceſſary to add to this account, that the oxygen in the gaſeous oxyd of azote appears to be very cloſely combined with the azote, ſince it can neither be ſeparated by the ſulphures of alkalis, muriat of tin, ſulphur, phoſphorus, nor carbon. It is ſomewhat ſingular, that hydrogen ſhould alone poſſeſs this property. During its detonation with ſulphurated and phoſphorated hydrogen gaſes, the hydrogen alone was conſumed.

Azote, the ſeparate exiſtence and peculiar nature of which were firſt diſcovered by Dr. Rutherford, appears, therefore, to be capable of being united to oxygen in the following proportions:

		Oxygen.		*Azote.*
Nitric acid,	-	79	+	23
Nitrous acid,	-	75	+	25
Nitrous gas,	-	68	+	32
Gaſeous oxyd of azote,		37	+	63
Atmoſpheric air,		27	+	73

See *Prieſtley's Exper. and Obſer.* Vol. II. p. 54.; *Deiman, Troetzwick, &c. Journ. de Phyſ.* Juillet 1793, p. 321. *Rutherford De Aere Mephitico*, p. 19.

V. SULPHURIC ACID.

[a] From this property of the ſulphuric acid, it has been propoſed to employ it as a *hygrometer*, to aſcertain the quantity of moiſture contained in any given portion of the atmoſphere. But the quantity of moiſture abſorbed by this acid is

found to vary, according to the ſtrength of the acid, the extent of ſurface expoſed, its temperature, &c.

[b] The congelation of the ſulphuric acid by cold, is a fact that was known to many of the older chemiſts. It is mentioned in the works of Kunkel, Bohn, Boerhaave, and Newman. Morveau found, that concentrated ſulphuric acid began to congeal at — 16° of Reamur's ſcale. It was changed in freezing into a whitiſh maſs ſimilar to ſnow. The acid at the bottom of the veſſel was not congealed. On dropping a bit of iron, or even calcareous earth, into this acid, no effervеſcence, no apparent action, was produced, owing, as Morveau ſuppoſes, to the extreme low temperature of the acid. In this ſtate alſo it was not diſcoloured by vegetable or animal ſubſtances. Sulphuric acid frequently aſſumes the concrete ſtate in degrees of temperature conſiderably above that of freezing water. Morveau obſerved, that ſulphuric acid which had been once congealed, underwent that change afterwards in a higher degree of temperature than acid which had never been congealed. The ſame obſervation was made by Mr. M'Nab, in his experiments at Hudſon's Bay. The difficulty of congelation in this, as in the nitric acid, does not at all ſeem to depend on the ſtrength of the acid This will appear very evident from the following ſtatement:

Sulphuric acid of the ſtrength of		*At the temperature of*
977	froze	+ 1°
918		— 26
846		+ 42
758		— 45

[c] The temperature produced by this combination is often ſo high as to boil water. Lavoiſier and La Place mixed two pounds of concentrated ſulphuric acid with one and a half of water, at the temperature of zero. The heat reſulting from this combination melted three pounds, two ounces, two gros of ice; a quantity equal to what would have been melted by two pounds, five ounces, ſeven gros forty-five grains of boiling water.

[d] There is only a very few of the metals that are directly ſoluble in concentrated ſulphuric acid. If iron and tin be diſſolved in ſulphuric acid, theſe metals deprive it of its oxygen, while ſulphur, the other conſtituent part of the acid, is diſengaged. But with moſt of theſe bodies the preſence of more or leſs water in the acid is required. In this caſe it becomes evident, from the evolution of hydrogen gas, that it is the water, and not the acid, which is decompoſed.

Fourcroy has lately had occaſion to change his opinion reſpecting the action of the ſulphuric acid on vegetable and animal ſubſtances. In an excellent memoir which Vauquelin and he have publiſhed on this ſubject, theſe chemiſts aſſert, that during this action no decompoſition of the acid whatever is produced. They attribute the changes which occur to the new affinities introduced among the conſtituent parts of the animal and vegetable ſubſtances. If the acid be added to a vegetable ſubſtance, it becomes diluted, a proof that water has been formed. Acetous acid will be found to exiſt in the product, and a portion of pure carbon will be ſeparated in the ſolid form.

Animal bodies, in addition to the carbon, hydrogen, and oxygen of which vegetables conſiſt, are found to contain a quantity of azote. When ſulphuric acid, therefore, is added to animal matter, the azote unites with a portion of the hydrogen to form ammoniac; while another portion of the hydrogen unites with the oxygen to form water. See *Annal. de Chem.* Tom. XXIII. p. 186.

[e] Prieſtley, Berthollet, and Bergman aſſert, that ſulphureous acid depoſits a portion of ſulphur when expoſed to a high temperature, and that by this means it is converted into ſulphuric acid. Fourcroy tried repeatedly to effect theſe changes, but without ſucceſs.

Oxygen gas, in the ordinary temperature of the atmoſphere, combines, though very ſlowly, with ſulphureous acid. This combination is promoted by the preſence of moiſture; but it is not ſufficient to change this acid into ſulphuric. In a high temperature, on the contrary, the oxygen combines readily, and ſulphuric acid is immediately formed.

Sulphureous acid gas combines readily with water cooled down to the freezing point by ice. During this combination, the ice is ſpeedily melted. If the liquor formed be expoſed to a high temperature, it begins to boil, a number of ſmall air bubbles riſe to the ſurface, and the liquor loſes by this operation a part of its odour and acidity.

This gas combines readily with ſulphuric acid in a low temperature. The mixture produced, freezes a few degrees below zero. When a piece of this ſolid ſalt is laid on a warm glaſs plate, it effervеſces, and ſoon becomes liquid and odorant.

Oils imbibe ſulphureous acid gas in the proportion even of ſix or eight times their own volume. It is imbibed alſo by ſulphuric ether, and poſſeſſes the property of diſſolving camphor. See *Berthollet Mem. de l'Acad.* 1782, p. 519.; *Berthollet Ann. de Chem.* Tom. II. p. 54.; *Lavoiſier Mem. de l'Acad.* 1777, p. 398.; *Fourcroy, Nicholſon's Journ.* Vol. I. p. 313.

[f] Dr. Prieſtley obſerved, that by burning ſulphur in atmoſpherical air, the air was diminiſhed 1-16th; and that the water over which the experiment was made had acquired an acid taſte. Scheele found, that atmoſpherical air was diminiſhed 1-6th, and oxygen gas 3-4ths, by the combuſtion of ſulphur. And Kirwan adds, that during this proceſs 100 grains of ſulphur abſorbed 420 cubic inches of oxygen gas. But it is to Lavoiſier that we are indebted for the firſt accurate account of the compoſition of ſulphuric acid.

This chemiſt found, that atmoſpherical air was diminiſhed from 1-8th to 1-10th of its volume by the combuſtion of ſulphur; while, at the ſame time, a quantity of concentrated ſulphuric acid was formed. The weight of this acid correſponded exactly with the ſum of the weights of the ſulphur and oxygen gas conſumed.

We have already had occaſion to mention the formation of ſulphuric acid, by diſtilling nitric acid with ſulphur. This proceſs was known in the laſt century, and is deſcribed by Motte la Faveur in a work publiſhed in 1671. See *Journ. de Phyſ.* Jan. 1789, p. 74. The ſulphureous acid likewiſe attracts oxygen from the nitric acid, and is by this converted into ſulphuric acid.

If a drop of water be let fall on heated ſulphur, the water will be decompoſed, hydrogen gas evolved, and ſulphuric acid produced. If we melt ſulphur and either of the fixed alkalis by heat, pulverize the maſs, and expoſe it in open veſſels to a ſlow fire, the ſulphur will combine with the oxygen gas of the atmoſphere, and a true ſulphat of ſoda or potaſh will be produced.

Sulphuric acid is produced by diſtilling oxygenated muriatic acid with ſulphur. If the oxygenated acid in its gaſeous ſtate be brought into contact with ſulphureous acid gas, the two gaſes loſe their elaſticity, and become liquid. When theſe acids are added together in the liquid ſtate, their colour and peculiar odour diſappear, and the mixture produced is found to conſiſt of ſulphuric and muriatic acids. Morveau ſays, this effect takes place even without heat.

Sulphureous acid is likewiſe formed, by diſtilling ſulphur with the oxyds of mercury, lead, iron, tin, and manganeſe. During this proceſs, the ſulphur ſeizes on the oxygen of the oxyd, while the oxyd is more or leſs completely reſtored to the ſtate of a metal.

We have ſtill another proof of the formation of the ſulphuric acid, in what has been termed the vitriolization of martial pyrites. This ſubſtance conſiſts of iron and ſulphur. On being expoſed to a moiſt atmoſphere, the ſulphur and iron abſorb oxygen gas, and are by this proceſs converted into a ſulphat of iron. See *Haſſerfratz Journ. de Phyſ.* Jeun 1787, p. 417.

Nor are the proofs of the decompoſition of ſulphuric acid leſs numerous. In diſtilling equal quantities of concentrated ſulphuric acid and iron filings, Monnet obſerved, that ſulphur was ſublimed into the neck of the retort. During this proceſs, a portion of the iron had been oxydated, and had united with the acid to form a ſulphat of iron.

In diſſolving four ounces of mercury in ſix of concentrated ſulphuric acid, Lavoiſier obtained ſulphureous acid gas, with an admixture of atmoſpherical air, and ſome oxygen gas. He expoſed two ounces of the ſulphat of mercury to a high temperature, and obtained a ſmall quantity of ſulphureous acid gas, with 87 cubic inches of oxygen gas.

In diſtilling concentrated ſulphuric acid with iron, Dr. Prieſtley obtained a great quantity of ſulphureous acid, and only a very ſmall quantity of hydrogen gas.

Sulphuric acid is ſaid to give out oxygen gas, and to become coloured and fuming by expoſure to the rays of the ſun.

Trootzwick and Deiman obtained oxygen gas, by paſſing the electric ſpark through concentrated ſulphuric acid. Van Marum found, that the volume of the ſulphureous acid gas was diminiſhed by the paſſage of this fluid. And Dr. Prieſtley remarked, that in making this experiment the inſide of the glaſs was covered by a blackiſh ſubſtance.

Iron immerſed in ſulphureous acid gas, and expoſed to the rays of the ſun in the focus of a burning glaſs, becomes oxydated, while a portion of the ſulphur is depoſited on the ſides of the veſſel in which the experiment is performed.

Geoffroy long ago underſtood the method of decompoſing the various combinations of the ſulphuric acid, by diſtilling them with oil, ſpirit of wine, reſin, carbon, &c. He remarked, that in his experiments a quantity of ſulphur was always produced.

Metals in the ſtate of powder decompoſe, in a ſtrong heat, the ſulphat of potaſh. They unite with the ſulphur, and form a kind of artificial pyrites.

Van Mons decompoſed ſulphuric acid, by digeſting powder of charcoal for ſome time in a ſolution of ſulphat of potaſh. During this proceſs, carbonic acid gas was evolved. By paſſing the ſulphuric acid through ignited charcoal, the ſame effect is produced. This decompoſition does not take place in the cold.

Sulphat of potaſh expoſed to the action of a burning glaſs in hydrogen gas, is converted to the ſtate of a ſulphure or *hepar*. The hydrogen in this experiment combines with the oxygen of the ſulphuric acid to form water.

If ſulphureous acid gas and hydrogen gas be paſſed through a well heated glaſs or porcelain tube, in the proportion of three parts of the latter to one of the former, the ſulphureous acid gas will be decompoſed, ſulphurated hydrogen gas produced, and a quantity of ſulphur depoſited in a ſolid form.

Sulphureous acid gas is decompoſed by phoſphorated hydrogen gas. As ſoon as the gaſes come into contact, white fumes appear, and they loſe their elaſticity. A yellow matter is depoſited, which ſeems to conſiſt of a mixture of phoſphorus and ſulphur. In this experiment, the hydrogen alone combines with the oxygen

Sulphurated hydrogen gas alſo decompoſes ſulphureous acid. The hydrogen unites with the oxygen of the acid, and the ſulphur is depoſited. The ſame effects happen when theſe ſubſtances are diſſolved in water If they be mixed in proper quantities, the odour peculiar to both will be completely deſtroyed. See *Morveau, Article* Acide Vitriolique, *Encyclopedie Methodique*, p. 353.; *Scherer Grundzüge*, ſ. 107.; *Scherer Nachträge*, ſ. 374.

[g] Another combination of ſulphur with oxygen has been deſcribed by ſome chemiſts. The proportion of oxygen which it contains is ſaid to be greater than that of ſulphuric; and hence it has been termed *oxygenated ſulphuric acid.* It muſt be confeſſed, however, that the exiſtence of this combination is ſtill a matter of doubt, ſince ſome of the moſt reſpectable chemiſts have in vain tried to procure it. See *Giobert Ann. de Chem.* Tom. XI. p. 178.; *Vauquelin Ann. de Chem.* T. VII. p. 287.

CHAPTER V.

ORDER II. SECONDARY, OR NEUTRAL SALTS.

UNDER the name of ſecondary ſalts, we comprehend ſuch matters as are compoſed of two primitive ſaline ſubſtances combined together. Theſe ſalts are called neutral, becauſe they do not poſſeſs the characters of primitive ſalts; that is to ſay, they are neither acid nor alkaline. There are, however, many ſalts, ſuch as borax, chalk, and alkalis, when united with the carbonic acid, which exhibit ſome of the properties of primitive ſalts, though in a leſs eminent degree. Theſe ſecondary ſalts have not ſo ſtrong a taſte as moſt of the primitive, their tendency to combination, and their ſolubility being leſs conſiderable; but the criterion which diſtinguiſhes them more eſpecially from the former is, that they cannot, like the primitive ſalts, communicate the ſaline properties to other bodies; their cryſtalline form is likewiſe a character much attended to by naturaliſts, and ſometimes indicates their nature, though it may be productive of error when too much depended upon.

The term, baſe, is commonly applied to the more fixed matter which enters into the compoſition of neutral ſalts. As this baſe, which is ſometimes volatile, communicates ſeveral general characters, ſufficiently uniform in the ſeveral combinations it makes with acids, we ſhall aſſume the name of the baſe to diſtinguiſh the genera of ſecondary ſalts, and ſhall therefore divide theſe ſalts into as many genera, as there are ſaline or alkaline baſes capable of being united with acids.

The firſt genus comprehends ſuch as are formed by the union of fixed alkalis with acids. We ſhall call them *perfect neutral ſalts*, becauſe the union of their component parts is very intimate.

The ſecond genus includes ſuch as are formed by the combination of the volatile alkali or ammoniac with acids. They are diſtinguiſhed by the name of *ammoniacal ſalts*, from that which has been given to their baſe by later chemiſts. They may likewiſe be called imperfect ſalts, becauſe they are much more eaſily decompoſed than ſalts of the firſt genus.

In the third genus are arranged ſuch neutral ſalts as have lime for their baſe. They are in general leſs perfect than thoſe of the ſecond genus, though lime has a ſtronger affinity to acids than ammoniac. Theſe ſalts are denominated *neutral calcareous ſalts.*

Magneſia, combined with various acids, conſtitutes the fourth genus. They are more decompoſable than thoſe of the laſt mentioned genus, becauſe lime and alkalis have a ſtronger affinity with acids than magneſia. They are diſtinguiſhed by the name of *magneſian neutral ſalts.*

The fifth genus comprehends ſuch as have pure argillaceous earth or alumine for their baſe. As alum is the principal of theſe combinations, the generic name of *aluminous ſalts* is given to them. Alkalis, lime, and magneſia, in moſt inſtances, decompoſe ſalts with an aluminous baſe.

Laſtly, We arrange in the ſixth genus, neutral ſalts, with a baſe of barytes or ponderous earth. Theſe ſalts, as well as moſt of the two preceding genera, are little known. We ſhall call them *barytic ſalts.*

It may eaſily be imagined, that theſe baſes, combined with the acids, whoſe properties we have examined, muſt afford a great number of neutral ſalts; and that this number would be ſtill more conſiderable, if, with Bergman, we were to admit, as peculiar ſalts, the union of the ſame ſubſtances with the acids which he calls *phlogiſticated,* and are, according to the modern doctrine, deprived of a part of their oxygen. But theſe compounds not being durable, but, on the contrary, ſubject to alteration, by the contact of air, which cauſes them in a ſhort time to become true neutral ſalts, I have not judged it neceſſary to add them to the number, but ſhall point out ſuch of their different properties as depend on the ſtate of their acids. We muſt likewiſe obſerve, that the alkaline baſes here enumerated, when combined with aqua regia, afford nitrous and marine ſalts, which may be obtained ſeparate, and are perfectly ſimilar to thoſe afforded by the unmixed acids; we ſhall therefore ſpeak of theſe combinations in treating of thoſe of the ſimple acids. As we have not hitherto examined any but the ſix principal acids, we ſhall treat only of the neutral ſaline combinations of theſe.

In the arrangement of the various neutral ſalts, we have followed the order of the affinities of the acids. That is to ſay, we begin with ſulphuric ſalts, after which we place nitric ſalts; and after them, the ſalts into which the muriatic, the boracic, and the fluoric acids enter; and, laſtly, we ſhall finiſh theſe details with the ſalts which contain carbonic acid, becauſe that acid is the weakeſt of them all. To denote all theſe ſalts, we ſhall adopt names compoſed of the acids and their baſes, in order that this nomenclature may expreſs the nature of each, and that there may no longer be any error on this point; we ſhall be careful to join a table, to exhibit the different names which each neutral ſalt has received at different times.

GENUS I. Perfect Neutral Salts, or Salts with Baſe of fixed Alkali.

Species I. Sulphat of Potaſh.

Sulphat of potaſh, called likewiſe *vitriolated tartar*, *ſal de duobus*, *polychreſt ſalt*, *or arcanum duplicatum*, is a perfect neutral ſalt, reſulting from the combination of the ſulphuric acid with potaſh, as its name indicates. It rarely exiſts in the mineral kingdom, but ſome vegetables contain a ſmall quantity of it.

This ſalt is uſually tranſparent and regular; its cryſtals vary in form and magnitude, according to the circumſtances in which they are obtained. When cryſtallized ſlowly in the ſmall way, it has the figure of tranſparent pyramids, with ſix ſides, nearly ſimilar to the points of roſe diamonds, and ſometimes ſix-ſided priſms, terminated by one or two hexahedral pyramids, like rock cryſtal. But if the evaporation be conducted with rapidity, the cryſtals are agglutinated and confounded, under the form of a ſolid cruſt, whoſe ſurface is full of irregular points or pyramids: the ſalt met with in commerce is of this kind. *Laſtly*, When the ſolution is expoſed to ſpontaneous evaporation, the cryſtals are frequently twelve-ſided, conſiſting of two hexahedral pyramids, united at their common baſe, and ſometimes ſeparated by a ſhort ſix-ſided priſm. It is true, that theſe laſt cryſtals are uſually foul, and never poſſeſs either the whiteneſs or the tranſparency of ſuch as are obtained by the firſt evaporation. But this difficulty exiſts in moſt of the neutral ſalts, in which the moſt regular figure, and the moſt perfect tranſparency, are ſeldom united.

Sulphat of potaſh has a bitter, diſagreeable taſte. It is not much altered by the action of heat; when thrown on red-hot coals, it flies into a number of ſmall fragments, attended with noiſe; this phenomenon, called decrepitation, depends on the ſudden rarefaction of the water contained in its cryſtals. Sulphat of potaſh loſes none of its eſſential properties by this decrepitation. It decrepitates in the ſame manner, and becomes dry, friable, and even pulverulent, by the loſs of its water, when expoſed to the action of heat in a crucible. It becomes red-hot before it melts, and is not fuſed but by the application of a conſiderable degree of heat. The melted maſs, when ſuffered to cool, is opaque, and not at all changed in its principles; for ſolution in water reſtores its cryſtalline and tranſparent appearance. If it be kept in ſtrong fuſion, in an open veſſel, it is volatilized without decompoſition.

Sulphat of potaſh is not changed by expoſure to air, but preſerves its figure and tranſparency without alteration; it is ſparingly ſoluble in water; and the quantity taken up varies conſiderably with the temperature of the fluid. According to Spielman, about 18 parts of cold water are required to diſſolve one of ſulphat of potaſh, whereas boiling water diſſolves near one-fourth of its weight; for Baumé aſſerts, that 4 ounces of boiling water diſſolve more than 7 gros 48 grains of ſulphat of potaſh*: it cryſtallizes partly by cooling, and ſtill more by evaporation: it retains but a ſmall proportion of water in its cryſtals, which ſeems to be the cauſe why it does not change by expoſure to air.

Sulphat of potaſh does not act on the ſimple earths: it has been obſerved, that the ſulphat of potaſh caſually contained among the ſalts uſed as fluxes in the making of glaſs, is found again in the ſcoriæ; and a conſiderable quantity may be obtained from glaſs gall.

Barytes decompoſes ſulphat of potaſh, according to Bergman, becauſe it has a ſtronger affinity than potaſh to the ſulphuric acid. If a ſmall quantity of this earth be added to a ſolution of ſulphat of potaſh, a precipitate is formed, conſiſting of ſulphat of barytes or *ponderous ſpar*, which is perfectly inſoluble, and will be examined under that baſe; the potaſh, in its cauſtic and pure ſtate, remains diſſolved in the liquid.

Lime and magneſia produce no change in ſulphat of potaſh;

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* That is to ſay, 2304 grains of boiling water, diſſolve 552 of vitriolated tartar. T. [illegible]

but many acids have a very conſiderable action on it. Rouelle firſt aſſured us, that it is poſſible to combine a larger quantity of ſulphuric acid with it than it naturally contains. His proceſs conſiſted in diſtilling concentrated ſulphuric acid over ſulphat of potaſh; the latter thus becomes impregnated with the acid, and acquires new properties, ſuch as thoſe of reddening tincture of violets, of being more ſoluble in water, acid taſte, and of effervescing with alkalis, ſaturated with carbonic acid, even after ſolution and cryſtallization. Baumé inſiſts, that this ſuperabundant acid is not really combined, and that the ſalt may be deprived of it, by being placed on bibulous paper, or ſand. Macquer, however, remarks, that the ſulphuric acid adheres with conſiderable force to ſulphat of potaſh, and thinks that this adherence ariſes from a peculiar affinity between theſe two ſubſtances, ſince, according to him, it cannot be deſtroyed by the action either of fire or water. I have ſeveral times made this combination of ſulphat of potaſh and concentrated ſulphuric acid, after the mannner of Rouelle, namely, by diſtillation in glaſs retorts, and have obſerved ſeveral facts not mentioned in the learned diſſertation of that author. The ſulphat of potaſh is melted into a kind of glaſs, of the appearance of white enamel, of a very acid taſte; but this vitreous frit did not attract the humidity of the air, but, on the contrary, exhibited appearances of efflorescence, when the acid formed only a fourth of the whole. The opinion of Macquer, that the adherence between this neutral ſalt and the acid is conſiderable, appears to be well founded, and doubtleſs ariſes from a peculiar combination.

Baumé has obſerved, that ſulphat of potaſh is remarkably affected by the acid of nitre; if this fluid be boiled on the ſalt, the nitric acid ſeizes the potaſh, and diſengages the ſulphuric acid. When the mixture is cooled, a cryſtallization of true nitre is perceived. It was at firſt concluded, that this decompoſition is the effect of heat; but the fuming ſpirit of nitre, poured on ſulphat of potaſh in powder, depoſits cryſtals of nitre at the end of a few hours. It has likewiſe been affirmed, that when the mixture becomes cold, the ſulphuric acid reſumes its power, and decompoſes the nitrat of potaſh in its turn. I have nevertheleſs kept by me, for ſeveral years, a mixture of ſulphat of potaſh, and ſpirit of nitre, at the bottom of which are ſaline cryſtals, capable of detonating on hot coals, which are not changed, though they are immerſed in the ſulphuric acid, ſeparated by the nitrous. Cornette has obſerved, that the concentrated muriatic acid likewiſe decompoſes ſulphat of potaſh, even in the cold. From theſe two facts, it ſeems, that the law of affinity, with reſpect to the different acids, is not ſo conſtant as has been thought: it muſt, however, be obſerved, with Bergman, 1*ſt*, That no more than one third of the ſulphat of potaſh is decompoſed in theſe experiments. 2*d*, That theſe decompoſitions do not take place, unleſs the ſulphat of potaſh contains a ſmall proportion of acid more than is neceſſary for its neutralization *. 3*d*, That the affinity of ſulphat of potaſh for ſulphuric acid, is the true cauſe of theſe decompoſitions, and that the ſulphat of potaſh undecompoſed, is very acid.

There is a decompoſition of ſulphat of potaſh, which requires to be more particularly attended to, and is effected by combuſtible bodies, particularly charcoal, and ſeveral metallic ſubſtances †. If a mixture of this ſalt and charcoal be ſtrongly heated in a crucible, the ſulphat of potaſh will no longer appear, but a combination of ſulphur, united to fixed alkali, will be found in its ſtead. Stahl regarded this experiment as a very proper demonſtration of the preſence or exiſtence of phlogiſton. Modern chemiſts account for the fact by the pneumatic theory. We ſhall explain both in the Hiſtory of Sulphur.

One hundred parts of cryſtallized ſulphat of potaſh contain, according to Bergman, about 52 parts of potaſh, 40 of ſulphuric acid, and 8 of water of cryſtallization.

This ſalt rarely exiſting in conſiderable quantities in nature, is produced artificially for the purpoſes of medicine. There are three methods of doing this: firſt, By directly combining ſulphuric acid with potaſh, ſulphat of potaſh is immediately produced, which may be cryſtallized by ſolution in water. The ſecond method is, to decompoſe, by the ſulphuric acid, ſuch neutral ſalts as are produced by the union of potaſh with other acids, ſuch as the nitrat, the muriat, and carbonat of potaſh, &c. in theſe decompoſitions, ſulphat of potaſh is always produced. The third method is, to decompoſe the earthy and metallic ſulphuric ſalts by means of potaſh. The latter precipitates the ſalino-terreſtrial ſubſtances, or the metallic oxyds united with ſulphuric acid. We ſhall deſcribe the two laſt methods of preparing ſulphat of potaſh, when we come to treat of the neutral ſalts employed in its preparation.

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* This curious ſubject is ably treated of by Bergman, in his Diſſertation on Elective Attractions. See page 47, Engliſh edition.

† See my *Memoires de Chimie*, page 225.—Note of the author.

Sulphat of potaſh is not uſed, except in medicine; it is a good purgative, and is ſometimes given alone, in the doſe of half an ounce or an ounce. It is moſt commonly adminiſtered in a doſe of one or two drachms, together with other purgative medicines. It is likewiſe uſed as a ſolvent in chronical diſorders, and eſpecially in coagulations of the milk; it is then given in doſes of a few drachms, in proper liquids; but its virtue, in this reſpect, is inferior to that of many other more ſoluble and leſs nauſeous ſalts. The ſulphureous, or ſulphuric acid with exceſs of ſulphur, united to vegetable alkali, forms a ſalt ſomewhat different from the preceding, which Stahl called ſulphureous ſalt, and which we ſhall name *ſulphite of potaſh.* This ſalt cryſtallizes in polyhedrons with ten faces, or in two tetrahedral pyramids, truncated at their baſes. It is very bitter, very ſoluble, and ſlightly deliqueſcent: almoſt all the mineral acids, and ſeveral vegetable acids, diſengage the ſulphureous acid in the form of gas, with efferveſcence. When expoſed to the air, the ſulphite of potaſh gradually abſorbs oxygen, and becomes ſulphat of potaſh [a].

Species II. Sulphat of Soda.

Sulphat of ſoda, named till now *Glauber's ſalt*, from the name of a German chemiſt, who diſcovered it, is perfectly neutral, and conſiſts of the ſulphuric acid, united to the mineral alkali, or ſoda. This ſalt has many of the properties of ſulphat of potaſh, and others which are peculiar to itſelf; it is equally cryſtallizable; is rather infuſible; is ſoluble in water; and does not unite with earths. Like ſulphat of potaſh, it is partly decompoſed by the nitric and muriatic acids; yet it differs greatly, in many of its properties, from that ſalt, as will appear more fully in the detail.

The ſulphat of ſoda is uſually in the form of regular cryſtals, either tranſparent or ſemi-opaque. Its cryſtals are priſms, with ſix unequal and ſtriated ſides, terminated with dihedral ſummits. But they have not often this regular form, but are ſubject to very conſiderable variations, as Romé de Liſle has ſhown at large in his *Cryſtallographie.* Its cryſtals likewiſe vary in ſize from that of very fine priſms or ſmall needles, to that of large priſms, near an inch in diameter, and ſix or eight inches in length, which are obtained in cryſtallizations in the large way. The taſte of this ſalt is at firſt cooling, and is ſucceeded by a ſtrong bitter. It does not alter blue vegetable colours.

Expoſed to heat, it melts quickly, and ſoon after becomes dry, and of an opaque white appearance, in which ſtate it cannot be melted but by a conſiderable heat, like the ſulphat of potaſh. On this occaſion, it is neceſſary to diſtinguiſh two kinds of fuſion, of which ſaline matters are capable. The firſt, called the aqueous fuſion, is produced by the water which enters into the formation of their cryſtals. It obtains only in ſuch ſalts as are more ſoluble in hot than in cold water; whence it follows, as a conſequence, that the water, which enters into the formation of the cryſtals, by being ſo heated, is rendered capable of diſſolving the ſaline matter. The aqueous fuſion is therefore merely a ſolution in hot water. The ſulphat of ſoda, therefore, after this fuſion, aſſumes a concrete form by cooling; but if the heat be urged, it becomes dry and white, and another fuſion enſues, which is called the igneous fuſion, becauſe produced merely by the fire. Sulphat of potaſh appears to be as difficult to melt as ſulphat of ſoda; and, like that ſalt, is volatilized by a violent heat, without ſuffering any alteration in its principles.

After the eſcape of the large quantity of water contained in the cryſtals of ſulphat of potaſh, it becomes converted into a fine white powder by expoſure to the air. This phenomenon is termed *efforeſcence*, becauſe the pulverulent down of the cryſtals reſembles, in whiteneſs and form, thoſe matters which are obtained in chemiſtry under the improper name of *flowers*. As this ſalt falls into powder when in contact with air, merely from the loſs of its water of cryſtallization, the efforeſcence proceeds more rapidly when the air is very dry, and conſequently greedy of moiſture. The phenomenon of efforeſcence is therefore very analogous to the drying of this ſalt by heat, both depending ſimply on the evaporation of the water, which is a conſtituent part of the cryſtals. But, as the water which enters into the cryſtals of ſulphat of ſoda, and, in general, of every other efforeſcent ſalt, is truly combined, the efforeſcence appears to take place by virtue of a kind of elective attraction between air and water, which is greater than between water and the ſaline matter. I have always conſidered effloreſcence as a phenomenon of this nature, and ſee no other way of explaining it. (Conſult my *Memoires de Chimie*). The ſulphàt of ſoda loſes near half its weight by effloreſcence, but its properties may all be reſtored, together with its cryſtalline form, by the addition of the water it had loſt. Though no medical author has attended to this circumſtance, it is certainly of conſequence to aſcertain the quantity of water which the ſulphat of ſoda loſes by effloreſcence, that the doſe of the ſalt preſcribed may be always of the ſame ſtrength. It ſhould be given with a deduction of about one third of its weight when in effloreſcence, compared with the ſame weight in fine tranſparent cryſtals.

The ſulphat of ſoda is very ſoluble in water, four parts of the fluid being ſufficient to diſſolve one of the ſalt; and a leſs quantity will ſerve in proportion as its temperature is higher: boiling water diſſolves nearly its own weight of this ſalt. It is not this property that the method of cryſtallizing it is founded. A ſtrong ſolution of the ſalt being left to cool, affords cryſtals ſo much the more beautiful, in proportion as the quantity of matter is larger, and the cooling more ſlow and gradual. When the operation is performed in the large way, ſtriated priſms, of ſeveral inches in length, are often obtained, in which the regular figure of the ſalt may be ſeen.

The ſulphat of ſoda has no more action on ſiliceous and aluminous earths than ſulphat of potaſh, and does not enter into the formation of glaſs. Barytes decompoſes this ſalt, but the ſalino-terreſtrial matters have no action whatever upon it.

Pure and cauſtic potaſh, mixed with a ſolution of ſulphat of ſoda, decompoſes it, becauſe of the ſtronger affinity of that alkali to the ſulphuric acid. To ſhow this fact, cauſtic potaſh muſt be poured into a hot and ſaturated ſolution of ſulphat of ſoda. This ſolution, which would have afforded cryſtals of this latter ſalt by cooling, affords only ſulphat of potaſh by evaporation, and the mother water contains the cauſtic ſoda.

The ſulphuric acid combines with ſulphat of ſoda, in the ſame manner as it does with ſulphat of potaſh.

The nitric and muriatic acids decompoſe ſulphat of ſoda in the ſame manner, and are attended with ſimilar appearances to thoſe mentioned in treating of ſulphat of potaſh.

When ſulphat of ſoda is ſtrongly heated with charcoal, or with certain metals, the ſulphuric acid paſſes to the ſtate of ſulphuric, as we ſhall obſerve in our hiſtory of that ſubſtance.

All the properties in which ſulphat of ſoda differs from ſulphat of potaſh, ſhow that the two fixed alkalis, which perfectly reſemble each other when conſidered in a ſtate of purity, are certainly different, ſince they form very different ſalts with the ſame acids. The proportion of the component principles is likewiſe very different in the two ſalts we have compared together, a centenary of ſulphat of ſoda containing, as Bergman finds, 15 parts of ſoda, 27 parts of ſulphuric acid, and 58 of water.

This ſalt is much more abundant in nature than ſulphat of potaſh. It is found in conſiderable quantities in the waters of the ſea, of ſalt ſprings, and eſpecially in many mineral waters: it can always be produced by art, by the three methods ſpoken of in the article of ſulphat of potaſh. It is not employed in the arts, but is much uſed in medicine; it is given as a cathartic medicine, from half a drachm to an ounce and a half, according to circumſtances. Its effects are more conſiderable and ſpeedy than thoſe of ſulphat of potaſh, becauſe it is more ſoluble in the fluids of the animal economy, and becauſe its taſte is more penetrating. We are ſtill ignorant of the properties of ſulphat of ſoda, or of the combination of ſulphureous acid with the mineral alkali [b].

Species III. Nitrat of Potaſh, or Common Nitre.

The nitrat of potaſh, common nitre, or ſaltpetre, is a perfect neutral ſalt, formed by the ſaturated union of the nitric acid with potaſh. Its taſte is cooling, and it does not alter the colour of ſyrup of violets. Its cryſtals are ſix-ſided priſms, terminated by dihedral pyramids, or cut off with a ſlope, and often perforated quite through in the direction of their axis.

Nitre exiſts in large quantities in nature, and is continually formed in inhabited places; it is found in great quantities upon walls which are ſheltered from the rain; it is then called ſaltpetre, or nitre *de houſſage*.

There appear to be three principal circumſtances that promote its formation; the firſt is, the preſence of chalk, or any other calcareous ſalt, as appears by its being collected from walls covered with plaſter, or from the ruins of ancient edifices. This ſalt is likewiſe found perfectly pure in chalky earths. The Duc de la Rochefoucault obtained it, in the proportion of one ounce in the pound, from the chalk of Roche Guyon.

The ſecond circumſtance neceſſary for the production of this ſalt, is the putrefaction, or ſpontaneous decompoſition of vegetable and animal matters. It is a well known fact, that places which are moiſtened with animal liquids, or contain animal matters in a ſtate of putrefaction, ſuch as dunghills, ſtables, privies, &c. produce much nitrat of potaſh. This conſtant obſervation has been applied to the formation of artificial nitre beds. Dry ditches are dug and covered with ſheds open at the ſides; theſe are filled with animal ſubſtances, ſuch as dung, the excrements of quadrupeds, or birds, with the remains of vegetables. Theſe matters are from time to time watered, eſpecially with water charged with animal or vegetable matters capable of putrefaction, and they are turned up to renew their ſurfaces from time to time. When the putrefaction is in an advanced ſtage, a ſmall portion of the matter is taken up and lixiviated, to aſcertain whether it contains nitre; and when it is found ſufficiently charged with that ſalt, the whole is lixiviated.

The third circumſtance which is found to favour the production of nitre, is the acceſs of air; this is the cauſe of the formation of the nitre found on walls, and for this reaſon it is that nitre beds require to be frequently turned over, in order that the air may touch them in all points. The neceſſity of the acceſs of air is ſtill more evidently ſhown by the nitre contained in chalk, as it is never found below a certain depth. When the three circumſtances here treated of are united, the production of ſaltpetre is very abundant. Nitre beds ought always to be conſtructed on theſe principles.

The theory of the formation of nitre has not been long known. Glauber, and many other chemiſts ſince his time, ſuppoſed nitre to exiſt ready formed in vegetables, from which they imagined it to paſs into animal ſubſtances, and to become diſengaged by putrefaction; but it was ſoon perceived, that vegetables do not contain a ſufficient quantity of nitre to account for what is obtained from nitre beds. Mr. Thouvenel, whoſe diſſertation on the formation of nitre was honoured with the prize of the academy, has made many experiments to diſcover its origin: he found, that the nitric acid is formed by the combination of an elaſtic fluid, diſengaged from animal matters in a ſtate of putrefaction, and pure air. He has likewiſe diſcovered, that the nitric acid, once formed, combines with calcareous earth, when only animal matters are made uſe of; and that the remains of vegetables are uſeful to afford the fixed alkali, or potaſh, which is the baſe of common nitre. But Mr. Thouvenel did not determine the nature of the gas, which is diſengaged from putrefying animal matters. It is to Mr. Cavendiſh that we are indebted for the proof that it is the ſame gas which conſtitutes one of the principles of the atmoſphere, under the name of phlogiſticated air, atmoſpheric mephitis, or azotic gas. He has formed the true nitric acid by the combination of this gas with vital air, by means of the electric ſpark [a].

The nitrat of potaſh is very ſubject to alteration by heat: it is quickly melted, and its fuſion is of the igneous kind; for it may be kept fluid for a conſiderable time, and even made red hot, without aſſuming the pulverulent form: when ſuffered to cool, after being melted, it fixes in an opaque maſs, called *cryſtal mineral*, which is as heavy, as fuſible, and as ſoluble in water, as the nitrat of potaſh itſelf. The cryſtal mineral of the ſhops differs from pure melted nitre, for it contains a ſmall quantity of ſulphat of potaſh, produced by the combuſtion of the ſulphur, which, according to the Paris Pharmacopeia, is in the proportion of a drachm in the pound.

If melted nitrat of potaſh be expoſed to the continued action of the fire, it becomes decompoſed, and is alkalized without addition. This operation ſucceeds equally well in a retort, and affords much inſtruction reſpecting the compoſition of the nitric acid: inſtead of obtaining the pure acid, a large quantity of an aeriform fluid is diſengaged, which may be collected under water, and is found to be vital air mixed with azotic gas. The alkaline reſidue uſually cauſes the retort to melt, and prevents the completion of the operation. Here we ſee the nitric acid converted entirely into vital air and azotic gas, by means of light and heat, which ſeparate its two principles. If the heat be not urged ſo as entirely to decompoſe the nitrat of potaſh, the alkali remains charged with a certain quantity of nitrous acid, or nitric acid, with an exceſs of nitrous gas. This acid may be diſengaged by means of vinegar; but if the nitre be more ſtrongly heated, the ſalt in this ſtate is termed *nitrit of potaſh*, on account of the ſtate of the nitrous acid which it contains, in the ſame manner as we term the combination of the ſulphureous acid with this alkali, the *ſulphat of potaſh.* The alkali remains pure and cauſtic. From the facility with which heat decompoſes nitrat of potaſh, we may obſerve, that in the making of cryſtal mineral, the ſalt ought not to be kept in fuſion too long, leſt the quantity of diſengaged alkali ſhould become too conſiderable, and render the effect of the medicine more violent than intended.

When nitrat of potaſh is expoſed to heat, in contact with combuſtible bodies, it is decompoſed with other appearances; a white and ſtrongly brilliant flame is produced, together with a kind of decrepitation. This phenomenon is called the detonation of nitre, and is a character by which it is eaſily known. Stahl ſuppoſed it to ariſe from the rapid combination of the nitrous acid with phlogiſton; and Mr. Baumé, in conformity to this theory, thinks that a nitrous ſulphur is formed, and inſtantly ſet on fire. In the year 1780, I read a memoir at the academy, in which I proved that nitrat of potaſh is not combuſtible, and that a nitrous ſulphur is not formed during its detonation; but that the phenomenon ariſes from the rapid combuſtion of the body added to the nitre, which is aſſiſted by vital air diſengaged from nitrat of potaſh ſtrongly heated. This theory is completely proved from the conſideration, 1*ſt*, That this ſalt never detonates without addition. 2*d*, That during the detonation of nitre, by the addition of inflammable matter, the latter is entirely conſumed. 3*d*, Becauſe the combuſtion of the inflammable matter is more complete, the larger the proportion of nitrat of potaſh. 4*th*, and *laſtly*, Becauſe the detonation of nitrat of potaſh takes place as well in cloſe veſſels as in the open air, which could not be effected but by means of the vital air afforded by that ſalt. This aſſertion is clearly proved by the proceſs for making the *clyſſus* of nitre, which is merely a detonation of this ſalt with different combuſtible matters, in cloſe veſſels: we ſhall only mention, in this place, the operation made with the addition of charcoal. Two or three large receivers, adapted together, are applied to a retort of earth or iron, in the upper part of which laſt is an aperture, which may be cloſed with a cover or ſtopper. The veſſel is heated, and when its bottom is red, the mixture of nitrat of potaſh and charcoal is thrown in by ſmall quantities at a time, through the aperture, which is immediately cloſed. During the detonation, the receivers are filled with vapours, part of which condenſes into an inſipid liquor, not at all acid, but frequently alkaline; the reſidue conſiſts of potaſh charged with carbonic acid, the nitric acid being entirely deſtroyed. A large quantity of gas is produced, which I have collected, by adapting to the upper part of the receivers, tubulated for that purpoſe, either a bladder, or tubes whoſe extremities were received under glaſs veſſels filled with water. This gas conſiſted, for the moſt part, of carbonic acid, mixed with a ſmall proportion of inflammable gas and azotic gas, which is one of the principles of nitric acid. The inflammable gas comes from the decompoſition of a portion of the water of nitre by the charcoal.

The reſidue, after the detonation of nitrat of potaſh with charcoal in a crucible, is improperly called *nitre fixed by charcoal;* it is potaſh combined with carbonic acid [b].

Very pure nitrat of potaſh is not at all altered by expoſure to air. It is very ſoluble, three or four parts of cold water diſſolving one part of nitre; and boiling water diſſolving twice its weight. It therefore cryſtallizes by cooling; and on this property is founded the art of extracting nitrat of potaſh from the old plaſter or rubbiſh in which it is contained. The ſaltpetre makers put the pounded rubbiſh into a caſk, with a hole in the bottom, and cover it with aſhes. Through this matter water is paſſed, care being taken to pour the firſt water upon ſuch matter as has already been waſhed, that the ſalts may be entirely extracted; and the water, which is already partly impregnated, is paſſed through caſks loaded with unwaſhed rubbiſh, in order that it may be entirely ſaturated. This lixivium is evaporated by heat in copper veſſels. The firſt pellicles, conſiſting of muriat of ſoda, or marine ſalt, are taken out. They call this ſalt *grain*, and are obliged by the regulations to carry it to the refining houſes. When the water is ſufficiently evaporated to become nearly ſolid in cooling, they pour it into veſſels, where the ſalt cryſtallizes. This nitrat of potaſh, which is very impure and dirty, is called nitre of the firſt boiling. Some chemiſts have thought, that the aſhes uſed by the ſaltpetre makers ſerve only to deprive the nitrat of potaſh of certain greaſy impurities; and this opinion appeared probable, from the conſideration that theſe aſhes contained ſcarcely any fixed alkali; and more eſpecially as the aſhes of tamariſk contain only ſulphat of ſoda. But this ſalt, as well as ſulphat of potaſh, is as ſerviceable for decompoſing the calcareous nitrat which abounds in the rubbiſh, becauſe it acts by the way of double affinity; as Mr. Lavoiſier has obſerved with reſpect to the lixiviated aſhes uſed by the ſaltpetre makers at Paris. We ſhall treat more fully on this fact when we ſpeak of calcareous nitrat.

Nitrat of potaſh, of the firſt boiling, is always very impure; it contains five other kinds of ſalt, namely, muriat of ſoda, nitrat of magneſia, calcareous nitrat, muriat of magneſia, and calcareous muriat, which muſt be ſeparated before the nitrat of potaſh can be had in a ſtate of purity. This is done by rediſſolving it in the ſmalleſt poſſible quantity of water, and clarifying this boiling liquor by the addition of bullock's blood, which carries all the impurities to the top of the liquor in the form of ſcum, by virtue of the property of coagulating which the aluminous coagulum poſſeſſes. This ſecond lixivium is evaporated, and affords a much purer nitrat of potaſh, called nitre of the ſecond boiling; it is ſtill vitiated by a certain quantity of muriat of ſoda, and mother water. It is purified a third time, by repeating the ſame proceſs, and is then much whiter. This is nitre of the third boiling. As it is cryſtallized haſtily, it has the form of large maſſes, of a confuſed figure; there is formed, however, in the middle of the veſſels, a bed of long and regularly formed cryſtals, called nitre in ſticks, which is not uſed in making good gunpowder, becauſe it retains a greater quantity of water in its cryſtallization than the nitre in large irregular maſſes, and is conſequently leſs proper for combuſtion.

Chemiſts and apothecaries purify nitre of the third boiling by new ſolutions and cryſtallizations, by which means they are certain of having very pure nitrat of potaſh, uncontaminated by any foreign matter, eſpecially the muriats with baſes of ſoda, lime, and magneſia, which are ſcarcely ever taken away entirely in the manufactories[c] *.

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* There is no fact more ſingular, in the opinion of naturaliſts and chemiſts, than the production of ſix ſpecies of ſalts in old mortar, and eſpecially the conſtant union of each alkaline baſe to a peculiar acid. The potaſh is always found united with the nitric acid, and the ſoda with the muriatic acid. There ſeems to be a peculiar relation between theſe different primitive ſalts, by which they are mutually applied to each other; for elſe, why ſhould not the muriat of potaſh, or nitrat of ſoda, be found? The ſame obſervation may be made reſpecting the

Nitrat of potaſh appears to be acted on by ſiliceous earth, ſince its acid may be obtained by diſtillation with ſand; this acid comes over colourleſs, but emits ſome vapours; the reſidue is more or leſs vitreous, according to the quantity of ſand made uſe of, and the degree of heat applied; the ſand appears to decompoſe the nitrat of potaſh by its tendency to combine with its alkaline baſe, ſince, in diſtillation, without an intermedium, it affords pure air, mixed with azotic gas, inſtead of nitric acid. I apprehend that this happens, becauſe, in the diſtillation of nitrat of potaſh without an intermedium, the alkali reacts on the acid, and contributes to its decompoſition; whereas, when this ſalt, mixed with ſand, is expoſed to heat, the latter ſubſtance tending to unite with the alkali, and form glaſs, prevents it from reacting on the acid, which therefore comes over unchanged. Argillaceous earths likewiſe decompoſe nitre. The clay commonly uſed is coloured. The diſtillers of aquafortis in Paris make uſe of an earth of the ſame kind; they introduce two pounds of nitre, of the ſecond boiling, with ſix pounds of coloured clay (of Gentilly), into earthen retorts of a peculiar form, termed *cuines*, which are placed in a row, on long furnaces, called galleries; their necks are inſerted in bottles of the ſame form, which ſerve as receivers. By this means they firſt obtain a tranſparent liquor, ſcarcely acid, which they call phlegm of aquafortis, which is followed by the acid itſelf, more and more concentrated; the reſidue is a red and hard earthy ſubſtance, which is uſed as a kind of mortar. This experiment is far from proving that clay decompoſes the nitrat of potaſh; for, 1*ſt*, The diſtillers employ a very impure nitre, which contains much nitre with an earthy baſe. 2*d*, They make uſe of a very compounded clay, which is often loaded with pyrites, whoſe ſulphuric acid may decompoſe the nitre. To aſcertain whether ſuch a decompoſition takes place, the whiteſt clay, or, which is ſtill better, the baſe of alum, or alumine, ought to be uſed. This earth not having ſo ſtrong a tendency as ſand to unite with alkali, and not forming glaſs with that ſalt, will not probably decompoſe the nitrat

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earthy ſalts. In fact, the quantities of muriat of magneſia, and of calcareous nitrat, greatly exceed thoſe of nitrat of magneſia, or calcareous muriat; whence it appears, that magneſia has a peculiar affinity with the muriatic acid, and lime with the nitric acid. *Note of the Author.*

of potaſh ſo completely as ſand. Mr. Baumé, however, affirms, that he obtained the acid of nitrat of potaſh by the addition of porcelain, and of clay baked into ſtone ware, which do not contain the ſulphuric acid *, though he was of opinion that the decompoſition of this ſalt was owing to a portion of that acid contained in clays.

Barytes decompoſes nitrat of potaſh, and ſeparates the alkali. Bergman, in his table of affinities, places this ſalino-terreſtrial ſubſtance before the alkalis, and immediately after the nitric acid.

Magneſia, lime, and alkalis, have no action on nitre.

The acids have a very ſtrong action on this ſalt, eſpecially the ſulphuric acid, which has a ſtronger affinity with alkalis than the nitric. If concentrated ſulphuric acid be poured on very dry nitrat of potaſh, a conſiderable efferveſcence is produced, and red vapours eſcape, which are nitrous acid. When the operation is made in a retort with a receiver, this acid, known under the name of the ſpirit of nitre, is collected. This proceſs is called by the name of Glauber's method of diſtilling ſpirit of nitre, becauſe that chemiſt firſt deſcribed it in an intelligible manner. It is neceſſary to leave a ſmall perforation in the receiver for the eſcape of the vapours of the nitrous acid. It was remarked, that theſe vapours being very difficultly condenſed, occaſioned two principal inconveniencies. The firſt was, the loſs of a conſiderable quantity of the ſpirit of nitre, which was diſſipated by the aperture: the ſecond conſiſted in the danger incurred by the operator, from the acrid and corroſive vapours. Mr. Woulfe, a learned Engliſh chemiſt, has contrived a method of remedying theſe inconveniencies. Inſtead of employing a perforated receiver, he uſes a receiver with two necks. The neck fartheſt from the retort conſiſts of a tube bent at right angles, the one part being horizontal and the other vertical; which laſt is inſerted in the neck of a bottle. From the ſides of this bottle proceed two tubes ſimilar to that laſt deſcribed, which paſs each into another bottle; and theſe are, in like manner, connected with two others, whoſe lateral apertures remain open. The firſt bottle is commonly empty; the collateral bottles con-

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* Theſe, as well as all other natural clays, contain a large proportion of ſiliceous earth. T.

tain each a certain quantity of water, in which the inferior extremities of the tubes of communion are plunged, the upper parts of the bottles remaining empty. The acid vapour, which is conducted by the tubes into the water, is there condenſed, either totally or in part. The part which eſcapes is conducted to the ſucceeding bottles; ſo that no part of the acid is loſt, and the operator is not in the leaſt incommoded. A quantity of vital air, which is diſengaged, paſſes out at the apertures of the exterior bottles, where it might be collected by a proper apparatus if neceſſary.

There is a principal advantage derived from this ingenious contrivance, which muſt not be paſſed over in ſilence. At the end of the operation, when the veſſels are ſuffered to cool, a vacuum is formed within; and the external air preſſing on the ſurface of the water in the laſt open bottles, forces it to return by the tubes into the firſt collateral bottles, and from them into the bottle neareſt the receiver. If the firſt bottle were not empty, and of a ſufficient magnitude to contain all the water of the following bottles, the acid liquors would paſs into the receiver; and as the ſtrongeſt nitrous acid is contained in that veſſel, it would be diluted by the addition of the fluid contained in all the bottles. This inconvenience would be ſtill more prejudicial in other diſtillations we ſhall have occaſion to ſpeak of, where it would not only diminiſh the force, but likewiſe alter the purity of the product.

To perform this diſtillation in a laboratory, four pounds of pure nitrat of potaſh, fuſed into the form of mineral cryſtal, is put into a tubulated ſtone-ware retort, placed in a reverberatory furnace. Tubulated retorts of glaſs may likewiſe be uſed, with a ſand bath. Two pounds and a half of concentrated ſulphuric acid is poured at once through the tube, and the aperture is ſtopped. The apparatus we have juſt deſcribed, and which we ſuppoſe to have been prepared and put together the evening before, muſt be adapted and expeditiouſly luted. The heat muſt be gradually raiſed till nothing more comes over. The diſengagement and paſſage of gas through the water in the bottles ſerve to direct the operator in managing the proceſs. If it be too rapid, the heat muſt be diminiſhed, leſt the whole maſs in the retort ſhould ſwell up and paſs into the receiver. If, on the contrary, it be too ſlow, the fire muſt be raiſed, to prevent abſorption. This valuable apparatus has therefore the additional advantage of directing the operator to conduct his proceſs to the beſt advantage.

The reſidue of this decompoſition conſiſts of ſulphat of potaſh, formed by the union of the ſulphuric acid with the alkaline baſe of nitre. This reſidue is known in pharmacy by the name of *ſal de duobus*, or *arcanum duplicatum*. It is uſually in the form of a white ſemi-vitrified maſs, full of cavities, produced during its ſwelling up by the heat; and it is very acid, on account of the exceſs of ſulphuric acid made uſe of, which is alſo the cauſe of its melting more eaſily, as we have obſerved in the hiſtory of ſulphat of potaſh. The ſtrong heat made uſe of in this proceſs, occaſions the nitrous acid to be very red and fuming, by diſengaging a portion of its vital air; and as it is always vitiated with a certain quantity of ſulphuric acid, it muſt be rectified by diſtilling it a ſecond time from one-fourth of its weight of nitre. Very pure nitrats of potaſh muſt be uſed, in order to obtain nitrous acid, whoſe effects can be relied on. The acid obtained from nitre of the ſecond boiling contains muriatic acid, and is a kind of aqua regia: diſtillation, properly managed, will ſeparate the marine acid, as Meſſrs. De Laſſone and Cornett have ſhown *.

Concrete boracic acid decompoſes nitre by the aſſiſtance of heat, and diſengages its acid in a conſiderable degree of concentration: this decompoſition is produced by virtue of its fixity, as the academicians of Dijon think. It muſt, however, be attributed, no doubt, in part, to the attraction between boracic acid, and the potaſh of the nitre.

Nitrat of potaſh is of great uſe in the arts: it is the principal ingredient in gunpowder, which we ſhall ſpeak of under the article of ſulphur. Burned with different proportions of tartar, it forms the ſubſtances called fluxes, which are employed in the art of aſſaying, to fuſe and reduce metallic ſubſtances.

It is frequently uſed in medicine as a febrifuge diuretic antiſeptic ſalt; it is adminiſtered in any convenient liquid, from ten or twelve grains, to the quantity of half a drachm or more; and it daily produces the moſt happy effects.

Species IV. Nitrat of Soda.

Nitrat of ſoda, which has been called cubic, quadrangular, or rhomboidal nitre is the perfect neutral ſalt reſulting from the combination of the nitric acid with ſoda.

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* Memoirs of the Academy for 1781, pages 653, 656.

It is uſually formed in regular rhomboidal cryſtals, of conſiderable magnitude; and is therefore more properly called rhomboidal nitre.

Its taſte is cooling, and rather more bitter than that of nitrat of potaſh.

Fire decompoſes it; but it decrepitates, and does not melt ſo eaſily as the nitrat of potaſh; but, like that ſalt, it gives out vital air, mixed with azotic gas, at the ſame time that it becomes alkalized.

It is ſlightly deliqueſcent when expoſed to air.

It is more ſoluble in cold water than the common nitre, two parts of water, at the ordinary temperature of ſixty degrees, diſſolving one part of the ſalt: it is ſcarcely more ſoluble in boiling water, and cannot therefore be had in regular cryſtals, but by ſlow evaporation. When a clear ſolution of this ſalt is expoſed in a dry place, rhomboidal cryſtals, upwards of half an inch, and ſometimes an inch long, are obtained at the end of ſome months. This proceſs, in general, is the beſt for cryſtallizing ſuch ſalts as are equally ſoluble both in hot and cold water.

Nitrat of ſoda detonates on coals, and cauſes the complete combuſtion of inflammable bodies; if it is heated, the detonation is ſomewhat leſs rapid than that of nitrat of potaſh.

Siliceous earth combines with its baſe, and diſengages the nitric acid; clay likewiſe ſeparates the acid, and affords a reſidue in the form of frit, which is porous and opaque when a ſtrong heat has been given.

Barytes decompoſes this ſalt, and diſengages the ſoda. Magneſia and lime do not ſenſibly change it.

Potaſh has a ſtronger affinity than its baſe with nitric acid, with which it forms nitrat of potaſh; this decompoſition is very eaſily ſhown. If a heated ſolution of nitrat of ſoda be divided into two parts, and cauſtic potaſh be added to one of them, it will afford priſmatic cryſtals of nitrat of potaſh, during its cooling; but no cryſtals will be obſerved in the other part, becauſe nitrat of ſoda does not cryſtallize by mere cooling, without evaporation.

The concentrated ſulphuric acid, added to nitrat of ſoda, diſengages the nitric acid with efferveſcence. Nitric acid is obtained by diſtillation from the mixture; the other mineral acids have no more action on this ſalt than on common nitre.

The neutral ſalts hitherto examined, namely, the ſulphat of potaſh and ſoda, and nitrat of potaſh, produce no effect whatever on nitrat of ſoda: if theſe ſalts be diſſolved together in the ſame water, they cryſtallize ſeparately, and each in its ordinary manner: the nitrat of potaſh, and ſulphat of ſoda, by cooling; and the ſulphat of ſoda and nitrat of ſoda, by evaporation. All theſe properties ſhow, that nitrat of ſoda differs from nitrat of potaſh in its form, taſte, deliqueſcence, ſolubility, cryſtallization by evaporation, and eſpecially its decompoſition by potaſh.

Nitrat of ſoda has not yet been found in nature, but is always produced by art, according to one of the five following methods: *1ſt*, The direct union of the nitric acid with ſoda. 2*d*, By decompoſing earthy nitrats, ammoniacal nitrat, and the metallic nitrats, by the ſame alkali. 3*d*, By decompoſing the muriat of ſoda by the addition of the nitric acid. 4*th*, By decompoſing ſulphat of ſoda by the fuming nitrous acid. 5*th*, and *laſtly*, By decompoſing nitric metallic ſalts by muriat of ſoda; in this caſe, in proportion as the muriatic acid unites with, and ſeparates the metal from the nitric acid; this laſt combines with the ſoda which quits the acid with which it was formerly united. A more minute account of this decompoſition, will be given under each of the ſalts in which they occur.

The nitrat of ſoda may be applied to the ſame uſes as nitrat of potaſh; but as it does not produce all the effects of this laſt ſalt (doubtleſs on account of its greater affinity with water), and likewiſe becauſe it is merely a product of art, no uſe whatſoever has yet been made of it, neither have all the experiments been made, which are neceſſary to afford a complete knowledge of its properties.

Species V. Muriat of Potaſh.

Muriat of potaſh, called formerly *the febrifuge ſalt of Sylvius*, is formed by the union of the muriatic acid with potaſh: it has been called *regenerated marine ſalt*, but improperly, as it differs from that ſalt in the nature of its baſe; its cryſtals are cubical, but almoſt always confuſed and irregular. Its taſte is ſalt, penetrating, bitter, and diſagreeable. In the fire, it decrepitates; that is to ſay, its cryſtals ſuddenly break, and fly in pieces, by the rarefaction of the water, which enters into their compoſition.

If the heat be then continued, and ſufficiently ſtrong, it melts, and is volatilized without decompoſition; it may ſerve as a flux to earthy and metallic ſubſtances; its principal uſe in theſe caſes is, that the matters being covered with it, the action of the other fluxes is more confined, and the alterations, which the acceſs of air might produce, are prevented.

The muriat of potaſh is not much altered by expoſure to air; it, however, ſlightly deliqueſces.

About three parts of cold water are required to hold one part in ſolution; hot water does not diſſolve a greater quantity; and therefore recourſe muſt be had to ſlow evaporation to obtain cryſtals: it is one of the moſt difficult ſalts to be procured in cryſtals of a certain magnitude.

Clay appears to decompoſe it in part; for muriatic acid is obtained by diſtillation of the muriat of potaſh with the clays found in the vicinity of Paris. This operation affords, in fact, only a ſmall quantity of acid, and its reſult is far from being ſuch as is obſerved with the nitrat of potaſh: ſand appears to have the ſame effect as clay on the muriat of potaſh.

Barytes ſeizes its acid, and ſeparates the potaſh, according to Bergman. Magneſia and lime do not at all change it.

The ſulphuric and nitric acids diſengage the muriatic acid with efferveſcence: and this phenomenon takes place more ſtrongly, in proportion as the muriat of potaſh is drier *. Such as has been deprived of its water of cryſtallization by decrepitating, produces a very ſtrong efferveſcence, attended with much heat, by the addition of concentrated ſulphuric acid. When theſe decompoſitions are made in retorts, muriatic acid is retained in the receiver, and ſulphat of potaſh remains behind, provided the ope-

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* We have already obſerved, in treating of the decompoſition of nitrat of potaſh by concentrated ſulphuric acid, that the nitric acid is diſengaged with a ſtrong efferveſcence. We here find the ſame phenomenon with the muriatic acid, the efferveſcence being conſiderably ſtronger with the muriat of potaſh, becauſe its acid has a very ſtrong tendency to aſſume the gaſeous ſtate: This is the general cauſe of all efferveſcences, the nature and differences of which have not been well known till lately. It was formerly thought that they aroſe from the diſengagement of air; but it is now well known, that the ſubſtance diſengaged is not air, but may conſiſt of any ſubſtance capable of aſſuming the aeriform aggregation; and for that reaſon we have obſerved, that the ebullition of water may be eſteemed a kind of efferveſcence. As this principle deſerves to be particularly attended to, we ſhall occaſionally repeat the preſent obſervation, in treating of the different neutral ſalts capable of being decompoſed by the acids. *Note of the Author.*

ration be made with the ſulphuric acid; but if the nitric acid be uſed, the receiver contains *aqua regia*, and nitrat of potaſh is found in the retort. The boracic acid likewiſe decompoſes muriat of potaſh by diſtillation, and diſengages the muriatic acid. As all theſe operations may be performed with muriat of ſoda, or common ſalt, we ſhall deſcribe them more fully under that article. The carbonic and fluoric acids have no action on muriat of potaſh.

The ſulphats and nitrats of potaſh and ſoda, do not act on this ſalt; but when diſſolved together in the ſame water, each cryſtallizes ſeparately, and in its uſual manner.

The muriat of potaſh is found naturally, but never in conſiderable quantities; it is found in ſea-water, and the water of ſalt ſprings, and it exiſts, though rarely, in the places where nitrat of potaſh is found; it is likewiſe met with in the aſhes of vegetables, and in certain animal fluids: it may be artificially produced, 1*ſt*, By direct combination of the muriatic acid with potaſh. 2*d*, By decompoſing earthy, ammoniacal, and metallic muriats by the ſame alkali. 3*d*, By decompoſing the ſulphat, or nitrat of potaſh, by means of the ſame acid, as Mr. Cornett has ſhown.

This ſalt was formerly employed as an excellent febrifuge, but it does not poſſeſs this property, otherwiſe than in common with all bitter ſalts; the ſulphats of potaſh and ſoda are at preſent preferred to it.

The muriat of potaſh is not uſed in the arts; its diſagreeable bitterneſs prevents its being uſed for culinary purpoſes, like the muriat of ſoda; its chemical properties agree with thoſe of the latter ſalt, excepting with reſpect to its bitter taſte, leſs degree of ſolubility, unchangeableneſs in the air, and leſs regular cryſtallization: for this reaſon we ſhall dwell no longer on its hiſtory.

Species VI. Muriat of Soda.

The muriat of ſoda, better known by the name of marine or culinary ſalt, is perfectly neutral, and is produced by the combination of the muriatic acid with ſoda. It will be perceived, that in the nomenclature hitherto adopted, the definition of the nature of theſe neutral ſalts is almoſt uſeleſs, ſince it is expreſſed in their denomination.

This ſalt is more abundant in nature than any other; it is found in prodigious maſſes in the internal parts of the earth, in

Spain, in Calabria, in Hungary, in Moſcovy, and more eſpecially in Wieliczka in Poland, near Mount Crapax, where the mines are very large, and afford immenſe quantities of muriat of ſoda. This ſalt, when contained in the earth, is ſeldom cryſtallized in any regular figure; it has various degrees of whiteneſs, and is often found coloured, in which ſtate it is called ſal-gem, becauſe it often has the tranſparence of gems: ſea-waters abound with this ſalt, as do likewiſe the waters of certain lakes and ſprings; and from theſe it is obtained by one or other of the four following general proceſſes[a].

The firſt conſiſts in ſpontaneous evaporation by the heat of the ſun, as is practiſed in the ſouthern provinces of France. Trenches are made near the ſea-ſide, lined with clay well rammed. Theſe are divided by low walls, into ſeveral compartments communicating with each other; and the flood-tide fills them with water, where it is retained by a kind of ſluice gates. Care is taken that the quantity of water ſhall be of an inconſiderable depth, that it may be eaſily evaporated by the ſun. When a ſaline pellicle is formed, the workmen break it, and it falls to the bottom, which they continue to do as long as any water remains. The ſalt is then raked together, and laid in heaps to dry. This mixed with every other which the ſea-waters contain, ſuch as ſulphat of ſoda and magneſia, the muriats of magneſia and lime; it is likewiſe contaminated by a portion of the clay, which forms the floor of the ſalt-pans; and laſtly, it contains iron, and mercury much divided; the latter of which is eaſily ſhown, by leaving a maſs of gold for ſome time in the ſalt, which becomes manifeſtly whitened. This very impure ſalt is known in France by the name of *ſel de gabelle.*

In the northern provinces of France common ſalt is obtained by artificial evaporation, effected by means of heat. In Arranchin they take the quickſands on which the ſea-water has depoſited its ſaline cryſtals; theſe are waſhed with the ſmalleſt quantity of water ſufficient to diſſolve the ſalt, and the water is then evaporated to dryneſs in leaden boilers. The ſalt thus obtained, is whiter and more pure than that of the proceſs before deſcribed[*].

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[*] Mr. Guettard has given an accurate account of this proceſs in the Memoirs of the Royal Academy for the year 1758.

There are many ſalt ſprings in Lorrain and Franche-Comté; the water of theſe ſprings is charged with different quantities of muriat of ſoda. At Montmorot, in the latter of theſe provinces, ſpontaneous evaporation is united to evaporation by heat: the water of the ſpring is pumped up into a large reſervoir, at the top of a building, or ſhed, beneath which are ſuſpended boards covered with little bundles of thorns or bruſh-wood; on theſe the water falls through ſmall cocks, and becomes divided into minute drops. The large ſurface of water thus expoſed to the air, which circulates quickly through theſe ſheds, cauſes an evaporation of nearly two thirds. Selenite is depoſited on the bruſh-wood; and when the liquid, upon trial with a kind of hydrometer, is found charged with ſalt to a certain degree, it is conveyed into large iron boilers, ſupported by bars of the ſame metal; theſe boilers are very large and ſhallow, and contain one hundred muids* of ſalt water. A briſk heat is applied; and as ſoon as the water boils ſtrongly, it becomes troubled, and an ocherous earth is ſeparated, in the form of ſcum; another ſalt, of difficult ſolubility, is next ſeparated, which is found to be ſulphat of lime, the workmen call it *ſchlot*, the ſchlat, mixed with a ſmall quantity of muriat of ſoda, ſulphat of ſoda, and earthy muriats. The ſcum is received in little troughs of cloth, placed round the ſides of the boiler, into which it is thrown by the circulation of the boiling liquor. Theſe troughs are taken out and cleared, from time to time, and repeatedly put in again, till a large quantity of ſmall cubical cryſtals, called by the workmen *pieds de mouches*, appear on the ſurface of the liquor. At this period, the troughs are taken away entirely; the fire is diminiſhed, and the muriat of ſoda is taken out with ladles, in proportion as it cryſtallizes in ſufficient quantity; the evaporation is continued till no more cubical cryſtals are afforded. The cryſtals are larger, the ſlower the evaporation; and the remaining fluid, called mother water, contains earthy muriats†[b].

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* The muid of wine contains 280 French pints.

† A neutral ſalt is prepared at Montmorot, which is known by the name of Epſom ſalt of Lorrain, but it is nothing more than ſulphat of ſoda, or Glauber's ſalt, whoſe cryſtallization has been diſturbed: it may be diſtinguiſhed from the true ſulphat of magneſia, or Epſom ſalt, by its effloreſcing in the air; whereas the Epſom ſalt, ſuch as we receive from England, is deliqueſcent. *Note of the Author.*

Wallerius mentions a fourth proceſs uſed in the north to obtain ſalt from ſea water. This water is expoſed in trenches on the ſea ſhore, where it forms ſo thin a ſtratum, that the cold of the atmoſphere ſoon freezes it; but as the ice conſiſts of mere water, the unfrozen part, after the ice is taken out, is of courſe more concentrated, and may be duly evaporated with a leſs degree of heat. It is conveyed into leaden boilers, and evaporated by fire[c].

The cryſtals of muriat of ſoda, are very regular cubes, and larger in proportion as the evaporation has been more ſlowly conducted; they adhere together by their edges, ſo as to form ſquare maſſes with a pyramidal cavity, having the appearance of ſteps within. Rouelle the elder has obſerved and deſcribed this phenomenon very accurately in his *Memoirs on Cryſtallization*, and Bergman has very ingeniouſly accounted for the fact.

The taſte of this ſalt is well known, and generally agreeable.

This ſalt, when expoſed to a briſk heat, burſts, and flies in pieces. This phenomenon is called *decrepitation*, and is produced, as we have already obſerved in treating of ſulphat of potaſh, and muriat of potaſh, &c. by the rarefaction of the water of cryſtallization. When all the water is evaporated in this manner, the decrepitation ceaſes, and the ſalt is reduced to a pulverulent form: if the heat be continued, it melts after ignition, and being poured on a ſmooth ſtone, becomes a kind of mineral cryſtal; but it is not at all altered, for its original form may be again reſtored by ſolution in water. Fire does not, therefore, decompoſe it; a very ſtrong heat volatilizes it without alteration.

Muriat of ſoda, when pure, is not ſenſibly changed by expoſure to air; it rather becomes dry than moiſt, and attracts humidity only in ſuch caſes as it contains muriats with earthy baſes, as in Sel de Gabelle.

It is very ſoluble in water; no more than three parts of this fluid being required to diſſolve one of the ſalt. Three ounces and a half of water diſſolve one ounce of ſalt very completely; and it is not more ſoluble in boiling than in cold water. Heat cauſes the ſolution to be made ſomewhat more quickly. The

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The addition of a fixed alkali to the ſolution of Epſom ſalt, occaſions a cloud, by the precipitation of the magneſia; but Glauber's ſalt, treated in the ſame manner remains tranſparent. T] cryſtals of this ſalt are obtained by a very ſlow evaporation. A number of ſmall points, *pieds de mouches*, form on the ſurface of the liquor, unite and produce a pellicle, more or leſs thick; ſometimes, inſtead of cubes, we obſerve a kind of ſquare and hollow pyramids, ſimilar in form to a mill-hopper. The manner in which theſe cubical cryſtals form ſquare and hollow pyramids, was obſerved by Mr. Rouelle to be as follows: When one cube is formed, its weight cauſes a depreſſion of the ſurface of the water around it; a ſecond cube formed near the firſt is attracted by it, or falls into the cavity, and adheres to one of its ſides; the ſame thing happens with regard to the other ſides, and this ſucceſſive accretion muſt produce hollow pyramids with their baſes uppermoſt, which, when arrived at a certain magnitude, ſink by their own weight. If the ſalt diſſolved, be pure, the water, after it has ceaſed to depoſite cryſtals by evaporation, will contain no ſaline matter; but the water of the ſea, and of ſaline ſprings, always contains ſalts with an earthy baſe. We may precipitate the earth by means of ſoda, as we ſhall afterwards explain under the article *Earthy Neutral Salts*. This is the method employed to obtain very pure muriat of ſoda[d].

Muriat of ſoda appears to facilitate the fuſion of glaſs; it always occupies the upper parts of the pots, and conſtitutes a great part of the matter called glaſs gall.

This ſalt is uſed to vitrify the ſurface of certain kinds of pottery, and to give them a kind of covering; this is done by throwing a certain quantity of this ſalt into the furnace, where it is volatilized, and applies itſelf to the ſurface of the pottery, occaſioning fuſion by its extreme heat. This is the kind of glazing uſed in the making Engliſh pottery*.

Siliceous earth does not alter this ſalt, though it ſeems to haſten its fuſion.

Pure clay has much leſs action on muriat of ſoda than on nitre, affording by diſtillation only a ſmall quantity of weak acid; the diſtillers of aquafortis, it is true, obtain the muriatic acid called *ſpirit of ſalt* in this manner, but they employ the moſt impure ſalt, which contains ſeveral muriats with earthy baſes; and likewiſe uſe a coloured and very impure clay.

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* The pottery here ſpoken of, is of the kind called ſtone ware. It is not probable that the vitrification is produced by any extreme heat in the vapours of the ſalt, but that the alkali of this laſt, uniting with the ſiliceous earth contained in the ware, compoſes a glaſs; part of the marine acid being at the ſame time ſet at liberty. Hence the ſurface of this pottery is always rough, the argillaceous part of the ware not being equally corroded by the alkali. The glaze of queen's ware is chiefly lead. T.

Barytes decompoſes muriat of ſoda, as well as all the other alkaline ſalts; as the experiments of Bergman ſhow. Lime and magneſia produce no change in muriat of ſoda, but theſe two ſalino-terreſtrial ſubſtances combined with the carbonic acid, may perhaps ſeparate its principles by the way of double elective attraction.

The cauſtic potaſh decompoſes muriat of ſoda, becauſe it has a ſtronger affinity than ſoda to its acid. A ſolution of muriat of ſoda, mixed with potaſh, affords muriat of potaſh by evaporation, and the mother water contains ſoda pure and diſengaged.

Acids have a powerful action on muriat of ſoda. If concentrated ſulphuric acid be poured on this ſalt, a very conſiderable inteſtine motion, attended with a ſtrong heat, is produced; a violent efferveſcence * is perceived, which ariſes from the muriatic acid diſengaged in the form of gas, as is evident from the white vapour it forms with the water of the atmoſphere; and by its ſtrong ſmell, not unlike that of ſaffron, when the vapour is much diluted. If this operation be made with a mercurial pneumato-chemical apparatus, much muriatic acid gas is obtained. Glauber firſt obſerved, and accurately deſcribed the decompoſition of marine ſalt by the ſulphuric acid; whence the acid obtained in this method has been called *Glauber's ſpirit of ſalt*; it was by examining the reſidue of this operation, that he diſcovered his *ſal admirabile* or ſulphat of ſoda.

Moſt authors direct in the diſtillation of muriatic acid to put decrepitated muriat of ſoda into a tubulated retort of ſtone ware, and to pour the half of its weight of concentrated ſulphuric acid through the tubulated part. Acid vapours are plentifully diſengaged, which paſs through the neck of the retort into two receivers, the firſt having two necks, and the ſecond being applied to its external neck; a ſmall hole is drilled in this laſt receiver that the vapours may eſcape, and the apparatus be prevented from burſting. In this operation, as well as in the common method of diſtilling nitrous acid, a large quantity of the pureſt muriatic acid is loſt, which is diſſipated in the form of gas, through the hole in the receiver; at the ſame time that the corroſive vapours, which fill the laboratory, are very inconvenient, and noxious to the operator. Baumé, to obviate part of theſe inconveniences puts a quantity of water into the retort, which being volatilized in the receiver, abſorbs a great quantity of the muriatic acid gas. But as this gas riſes much ſooner than the water, the loſs is nevertheleſs very conſiderable. Woulfe, by a method very different from that of Baumé, procures the ſtrongeſt and moſt concentrated muriatic acid: inſtead of volatilizing the water after the vapours of muriatic acid, he cauſes the gas to paſs through that liquid, by means of the apparatus deſcribed at the article *nitre.*

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* The efferveſcence is as evident in this operation, as in the union of the ſame acid with lime and alkalis, ſaturated with carbonic acid. It takes place, therefore, every time that a body, diſengaged from its combination, is volatilized under the form of gas. It may be produced by carbonic, muriatic, nitric, ſulphuric, fluoric acids, &c. and ought not to be attributed to the diſengagement of air.

Eight ounces of diſtilled water are put into the collateral bottles, when a mixture of two pounds of muriat of ſoda, and one of concentrated ſulphuric acid, is uſed. The muriatic acid gas, conducted by the tubes, is diſſolved in the water of the bottles; the combination of the gas heats the water almoſt to boiling; and the quantity of air abſorbed is nearly equal in weight to that of the water. When it is thus far charged, it diſſolves no more, and becomes cold; but the gas paſſing into the ſecond collateral bottles, unites with, and heats the water they contain.

This ingenious proceſs agreeing well with the known properties of the muriatic acid gas poſſeſſes ſeveral advantages. 1*mo,* It prevents the inconveniencies ariſing from the diffuſion of the acid vapours in the air. 2*do,* It prevents the very great loſs of acid, which was unavoidable in the old proceſs. 3*tio,* It affords the muriatic acid in a ſtate ſtronger, more concentrated and fuming than can be otherwiſe procured. 4*to,* This acid is at the ſame time very pure, being formed entirely by the gas diſſolved in water. It is therefore very white, while that formerly obtained was always of a citron colour; a circumſtance which has led chemiſts into the error of aſſuming that character as diſtinctive of the acid; the portion of liquid acid, which in this proceſs is condenſed in the receiver, is yellow, and contaminated by the foreign matters which riſe from the matters contained in the retort, in the ſame manner as happens in the ancient proceſs. 5*to,* The new method enables the artiſt to judge of the neceſſary degree of heat, and of the mode of conducting the operation by the more or leſs rapid paſſage of the muriatic acid gas through the water in the receivers. *6to*, and *laſtly*, An additional and moſt valuable advantage of this method is, that it accurately aſcertains the quantity of acid contained in any neutral ſalt, no portion thereof being loſt.

The nitric acid likewiſe decompoſes muriat of ſoda; but as it is itſelf volatile, it riſes and unites with the acid of this ſalt, forming the mixture called nitro-muriatic acid, or *aqua regia.*

Baron has diſcovered, that boracic acid diſengages the acid of muriat of ſoda, by the aſſiſtance of heat; the reſidue of this operation is very pure borat of ſoda.

The carbonic and fluoric acids have no evident action on muriat of ſoda.

The neutral ſalts, hitherto deſcribed, do not act on this ſalt; the ſulphats and nitrats of potaſh and ſoda, and the muriat of potaſh being diſſolved in the ſame water with muriat of ſoda, each of theſe ſaline matters cryſtallizes in its own particular manner; the muriat of ſoda is one of thoſe which cryſtallizes firſt, during the progreſs of the evaporation, and is mixed with a ſmall quantity of the ſulphat and muriat of potaſh; but the ſulphat of ſoda and nitrat of potaſh remain longer in ſolution, and cryſtallize by cooling. The mother water, from which marine ſalt has been obtained in Lorrain, is conveyed while hot into caſks, where it is continually agitated during its cooling; by which means the ſulphat of ſoda cryſtallizes confuſedly, in ſmall needles, reſembling the true Epſom ſalt, or ſulphat of magneſia.

The uſes of muriat of ſoda are extenſive and numerous; it is employed, 1ſt, In the glazing of pottery, by producing a ſlight fuſion of the exterior ſurface of the ware. 2d, In glaſs-making, to render the glaſs whiter and clearer. 3d, In docimaſtic eſſays, either as a flux to facilitate the precipitation of metals from the ſcoriæ, and to prevent their alteration by the contact of the atmoſphere.

Common ſalt is at preſent applied to another uſe, of more conſequence than thoſe we have mentioned; namely, to the extraction of ſoda, which daily becomes more ſcarce, and is indiſpenſably neceſſary in many of the arts: ſeveral perſons in England poſſeſs this ſecret, and extract the ſoda from ſea-ſalt in the large way. Some chemiſts have thought that litharge is capable of decompoſing the muriat of ſoda in the cold, and by ſimple maceration: it appeared, that, by uniting the two properties, the firſt of containing carbonic acid capable of attracting the ſoda, and the ſecond of forming an inſoluble ſalt with the muriatic acid, which would therefore be eaſily ſeparated from the alkaline lixivium, the litharge might act by a double affinity; but my trials on this head have proved that the proceſs is inſufficient. Scheele found that iron, plunged in a ſolution of muriat of ſoda, became covered with ſoda, ſaturated with carbonic acid. He had the ſame ſucceſs with the ſulphat and nitrat of ſoda, or Glauber's ſalt, and rhomboidal nitre, treated in the ſame manner. He diſcovered, that quicklime, mixed with a ſolution of muriat of ſoda, and left in a moiſt cellar, afforded an efflореſcence of ſoda, and that calcareous muriat was formed. Cohauſen announced this fact, in the year 1717. Morveau has proved that theſe decompoſitions are effected by favour of the carbonic acid; becauſe a ſolution of the ſulphat and muriat of potaſh, poured into lime-water, rendered turbid by the carbonic acid, became clear and tranſparent; and becauſe there is no precipitate afforded by pouring water impregnated with carbonic acid into a mixture of lime-water, and a ſolution of theſe ſalts. Theſe facts are the data from which we muſt ſet out in endeavouring to diſcover a way of extracting ſoda from marine ſalt, and in forming eſtabliſhments for this purpoſe, on the large ſcale.

Muriat of ſoda is univerſally uſed as a ſeaſoning for food; it facilitates digeſtion, by producing a commencement of the putrid alteration in the alimentary ſubſtances. For though it is well aſcertained, by the experiments of Pringle, M'Bride, &c. that it retards putrefaction, and, like moſt ſaline matters, is a powerful antiſeptic when added in conſiderable quantities to animal matters; yet it acts in a very different manner when mixed with thoſe ſubſtances in a ſmall doſe, ſince it cauſes them to putrefy more quickly. This fact is proved, by the experiments of the author of Eſſays intended to ſerve as an hiſtory of putrefaction, and likewiſe by thoſe of Mr. Gardane.

This ſalt is not of leſs utility in medicine; it is put into the mouth, and employed externally as a powerful ſtimulant in apoplectic or paralytic diſorders; and is in many caſes a good diſcuſſive. It is particularly recommended by Ruſſel (*De Tabe Glandulari*) for lymphatic tumours, ariſing from a ſcrophulous diſpoſition of the animal ſyſtem. I have myſelf obſerved its happy effects in many diſorders of this nature. It proves purgative when adminiſtered in a doſe of ſeveral drachms. As it is the impure ſalt that is commonly uſed, its effects are in part to be attributed to the calcareous and magneſian muriats which it contains.

Species VII. Borat of Soda, or Superſaturated Borat of Soda*.

The borat of ſoda, or common borax, is a neutral ſalt, formed by the combination of the boracic acid, with exceſs of ſoda.

The hiſtory of this ſalt, which comes to us from the Eaſt Indies, is very uncertain: it is not well known whether it be a natural or an artificial product: in fact, though the diſcovery of boracic acid, diſſolved in the waters of certain lakes in Tuſcany, afford reaſon to conclude that borax of ſoda is a natural product, there are many facts which we ſhall mention that ſeem to prove, that this ſalt may be entirely formed or produced by certain proceſſes. And we may probably, in future, poſſeſs artificial methods of forming borax, in the ſame manner as we have artificial nitre beds in ſeveral parts of Europe.

Borax is found in commerce in three different ſtates; the firſt is crude borax, tincal, or chryſocolla, which comes from Perſia. It is in greeniſh maſſes, of a greaſy feel, or in opake cryſtals of an olive green, which are ſix-ſided priſms terminated by irregular pyramids. There are two varieties of theſe green cryſtals differing in magnitude: this ſalt is very impure by the admixture of foreign matters.

The ſecond ſpecies of borax is known by the name of borax of China. It is rather purer than the foregoing; in the form of ſmall plates or maſſes irregularly cryſtallized, of a dirty white. It appears to conſiſt of fragments of priſms and pyramids confounded together without any ſymmetrical arrangement; a white powder is obſerved on the ſurface, which is thought to be of an argillaceous nature.

The third ſpecies is the Dutch or purified borax. It is in the form of portions of tranſparent cryſtals of conſiderable purity; pyramids with ſeveral facets may be recognized, the cryſtallization appearing to have been interrupted. This form ſhows to a certainty that the Dutch refine this ſalt by ſolution and cryſtallization.

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* Hitherto we have ſpoken, firſt, of ſuch neutral ſalts as have potaſh for their baſe; but with reſpect to ſalts, which contains the boracic acid, we are under the neceſſity of beginning with that which has ſoda for its baſe, becauſe it is the only one we are well acquainted with. *Note of the Author.*

Laſtly, The Meſſrs. Leſgulliers, chemiſts in the *Rue des Lombards*, at Paris, prepare a purified borax, in no reſpect inferior to that of Holland, and perhaps even of greater purity.

Beſides theſe four kinds of borax, an apothecary at Paris, M. la Pierre, imagined he has diſcovered that it is continually formed in the ſoap ſuds and refuſe waters of the kitchen, which a certain individual preſerves in a kind of ditch, and from which at the end of a certain time he obtains true borax in fine cryſtals. This fact, firſt announced ten years ago, has not ſince been confirmed. All that we can deduce from the known facts concerning its formation, is ſimply, that it is produced in ſtagnant waters, which contain fat matters. Some authors affirm, that it is produced by art in China; a mixture of greaſe, clay, and dung, is ſaid to be depoſited in a ditch, ſtratum ſuper ſtratum. This mixture is ſprinkled with water, and ſuffered to remain for ſome years, at the end of which time the maſs is lixiviated, and affords crude borax by evaporation. Others have ſuppoſed that it is obtained from water, which filters through copper mines. Baumé poſitively affirms, that the former of theſe proceſſes ſucceeded very well with him. *Chim. Exper.* Tom. II. p. 132.

Purified borax has a very regular form; its cryſtals are ſix-ſided priſms, two of the ſides being commonly larger than the others terminated by trihedral pyramids. Its cryſtallization is however ſubject to conſiderable varieties; its taſte is ſtyptic and urinous, and acts ſtrongly on the fibres of the tongue; it converts the ſyrup of violets to a green. We give to it the name of borax, in order to diſtinguiſh it from that which is ſaturated with boracic acid, or the true *borat of ſoda.* We call it alſo borat ſuperſaturated with ſoda, in order to point out the nature of its combination.

Borax expoſed to heat quickly melts, by means of its water of cryſtallization; it loſes this water gradually, ſwelling up, and conſiderably increaſing in magnitude, and is then in the form of a light porous and very friable maſs, diſtinguiſhed by the name of calcined borax. This appearance ariſes from the eſcape of the vapours of water, which raiſe the half dried ſalt into the form of light pellicles, in which form they become dry, ſo as to leave cavities between each other. Calcined borax is not at all altered in its compoſition; nothing being driven off by the heat, but the water of cryſtallization, which is ſomewhat more than a third of its weight. Its original form may be reſtored by ſolution in water and cryſtallization; but when calcined borax is more ſtrongly heated, it melts into the form of a tranſparent greeniſh glaſs, which tarniſhes in the air, and is ſoluble in water. The nature of the borax is not at all changed by this fuſion; all its properties being reſtored by ſolution in water and cryſtallization.

Air produces no change in this ſalt, excepting the depriving it of a part of its water of cryſtallization; and by that means cauſing an efflo reſence on its ſurface. It ſeems that this efflo reſcence is not always the ſame in the different kinds of purified borax. The borax of China effloreſces much leſs than that of Holland; and the borax purified at Paris ſtill leſs than either. This trifling difference doubtleſs depends on the proceſſes made uſe of in its purification, the manner of cryſtallizing, and the quantity of water its cryſtals contain, accordingly as they have been formed with more or leſs rapidity; and perhaps, likewiſe, on the different proportions of the acid of borax and ſoda, which enter into its compoſition.

Borax is very ſoluble in water; twelve parts of cold, or ſix of boiling water, are required to diſſolve one of the ſalt; its cryſtals may therefore be obtained by cooling, but the fineſt and moſt regular are formed by ſuffering the cold ſaturated ſolution to evaporate ſpontaneouſly in the ordinary temperature of the atmoſphere.

Borax ſerves as a flux to vitrifiable earths, with which it forms a good glaſs. It is employed in making artificial precious ſtones, or falſe gems.

It vitrifies clay, but much leſs completely than ſiliceous earths; from this property it adheres to and glazes the inſide of crucibles.

The action of barytes, and of pure magneſia, on borat of ſoda, is not known. Mr. Bergman, however, places theſe two ſubſtances before the alkalis in the firſt column of his table of affinities; which implies that they are capable of decompoſing this ſalt: but in his diſſertation he affirms, that the affinities of ponderous earth and magneſia with the the acid of borax are not yet accurately determined.

Lime has really a ſtronger affinity with the acid of borax than ſoda has; lime-water precipitates the ſolution of this ſalt; but in order to decompoſe it perfectly, it is neceſſary to boil quicklime with borat of ſoda; the precipitate which is then formed is an almoſt inſoluble ſaline compound of lime with the boracic acid, and the cauſtic ſoda remains diſſolved in the water.

Potaſh decompoſes borat of ſoda, as well as every other neutral ſalt with baſe of ſoda: ammoniac does not act upon it at all.

Acids act ſtrongly upon this ſalt; if concentrated ſulphuric acid be gradually poured into a boiling ſolution of borat of ſoda, till the liquor contains a ſlight exceſs of acid, a very abundant precipitate, in the form of ſmall brilliant ſcales, is obtained by cooling. This muſt be waſhed with diſtilled water, and dried: it is the boracic acid. The liquid being evaporated, and cooled ſucceſſively for ſeveral times, affords more boracic acid; and at laſt ſulphat of ſoda is obtained, by the union of the alkaline baſe of the borax to the ſulphuric acid.

The nitric and muriatic acids decompoſe borat of ſoda in the ſame manner, becauſe, like the ſulphuric acid, they have a ſtronger affinity with ſoda than the boracic acid has. The reſidues of theſe evaporations afford nitrat or muriat of ſoda. The diſcovery of boracic acid appears to have been made by Beccher, but it is commonly attributed to Homberg, who firſt accurately deſcribed a proceſs for obtaining it, in the Memoirs of the Royal Academy for 1702. The proceſs conſiſted in diſtilling a mixture of calcined ſulphat of iron, borat of ſoda, and water: he called the ſublimed ſalt, volatile narcotic ſalt of vitriol, on account of the firſt mentioned ingredient, which he ſuppoſed to contribute greatly to its formation. Louis Lemery, eldeſt ſon of the famous Nicholas, has made many experiments with borat of ſoda; and in the year 1728, he obſerved, that boracic acid, called then ſedative ſalt, may be obtained by means of the pure ſulphuric, nitric, and muriatic acids; but he always uſed the method of ſublimation. It is to Geoffroy the younger, that we are indebted for a complete analyſis of borat of ſoda, in the year 1732, he obtained boracic acid by evaporation and cryſtallization; and by examining the reſidue of the proceſs, he ſhowed, that ſoda is one of the principles of borax.

The experiments of Baron on this ſalt, preſented to the Academy in the years 1745 and 1748, exhibit two important facts in addition to thoſe before known. The firſt is, that vegetable acids likewiſe decompoſe this ſalt; and the ſecond is, that the true borax may be recompoſed by uniting boracic acid with ſoda, by which it is proved, that the acid exiſts ready formed in the ſalt, and that the other acids made uſe of in procuring it do not at all contribute to its formation.

The fluoric acid, and even the carbonic acid, though one of the weakeſt, are capable of decompoſing borat of ſoda, and ſeparating the boracic acid. This laſt readily unites with borax, whoſe alkaline baſe requires for its perfect ſaturation ſomewhat more boracic acid than is equal to the weight of the borax itſelf. Bergman even thinks that this ſalt is imperfectly ſaturated, and that its alkaline properties cannot be removed, but by this addition of boracic acid: the properties of this neutral ſalt, or the true borat of ſoda, have not yet been fully inquired into.

Neutral ſalts, conſiſting of a fixed alkali united with the ſulphuric, nitric, or muriatic acids, have no action on borat of ſoda.

This ſalt, fuſed with combuſtible matters, as for example, charcoal, acquires a reddiſh colour, but the alteration it ſuſtains is not well known.

Borax is exceedingly uſeful in ſeveral manufactures; it is employed as an excellent flux in the art of glaſs-making, as well as in aſſays. It is advantageouſly uſed in ſoldering, which it promotes by aſſiſting the fuſion of the ſolder, by ſoftening the ſurfaces of the metals, and by defending them from the contact of the air, by which they would otherwiſe be calcined. Borax was formerly much uſed in medicine, but it is at preſent entirely abandoned*.

Species VIII. Borat of Potaſh.

We give the name of borat of potaſh to the combination of boracic acid with potaſh. It is well known, that theſe two ſaline ſubſtances are ſtrongly diſpoſed to unite, and that a neutral ſalt, analogous to borat of ſoda is produced in this operation; the reſidue of nitrat of potaſh decompoſed by boracic acid is of this kind. Mr. Baumé affirms, that this reſidue is a white maſs, imperfectly melted, and that by ſolution in water it affords a ſalt in ſmall cryſtals. The borat of potaſh is therefore fuſible, ſoluble, and cryſtallizable. The pure acids decompoſe this ſalt, as well as borat of ſoda; but nothing more is known concerning this ſalt which has been ſcarcely at all examined. Baron was acquainted with the poſſibility of producing this ſalt, by the direct combination of boracic acid with potaſh: he has even made a diſtinction between this and the common borax, or that with baſe of ſoda, but he ſays nothing of its properties.

Species IX. Fluat of Potaſh.

By this name, according to the rules of the new nomenclature hitherto adopted, we may diſtinguiſh the combination of the fluoric acid with potaſh. This kind of neutral ſalt has hitherto been only ſlightly examined by Scheele and Boullanger. It is always in a gelatinous form, and never cryſtallizes. According to Scheele, it is acrid, cauſtic, and deliqueſcent, when dried and melted: he compares it in this ſtate to the liquor of flints. It appears that the fire diſengages the fluoric acid, and that the ſiliceous earth, always taken up by this acid, melts into a ſoluble glaſs by means of the potaſh.

Fluat of potaſh is very ſoluble in water, of which fluid it always retains ſo large a quantity, as to render it incapable of taking the cryſtalline form. When well ſaturated, its ſolution produces no change in ſyrup of violets.

The action of the ſiliceous, argillaceous, barytic, and magneſian earths on this ſalt, are not known.

According to Scheele and Bergman, lime has a ſtronger affinity than potaſh, with the fluoric acid. Fluat of potaſh is immediately decompoſed by lime-water; the lime unites with the fluoric acid, and forms an inſoluble ſalt, which renders the liquor muddy, and is the fluat of lime. We ſhall hereafter obſerve, that the neutral ſalts formed by the carbonic acid and fixed alkalis, are likewiſe decompoſed by lime. We have alſo ſeen that borat of ſoda, is precipitated by lime-water; the fluoric is not, therefore, the only acid which has a ſtronger affinity to this ſalino-terreſtrial ſubſtance than to fixed alkalis.

Concentrated ſulphuric acid decompoſes the fluat of potaſh and diſengages its acid, which, according to Boullanger, exhibits the white vapours and ſmell peculiar to muriatic acid. When this experiment is made, in a proper apparatus for diſtillation, the fluoric acid is collected in the ſame manner as the acids of nitrat of potaſh and muriat of ſoda, when decompoſed by the ſulphuric acid.

The action of the nitric and muriatic acids, as well as that of the neutral ſalts upon fluat of potaſh, has not, that we know of, been examined into.

This ſalt is not applied to any uſe.

Species X. Fluat of Soda.

We uſe this name to denote the ſaturated combination of the fluoric acid with ſoda. Like the preceding ſalt, it has been very little examined. Meſſrs. Scheele and Boullanger ſpeak of this combination, but their accounts do not agree.

Scheele affirms, that ſoda united to the fluoric acid, forms a jelly, like the preceding ſalt; Boullanger, on the contrary, affirms, that this combination affords very ſmall, hard, brittle cryſtals, in oblong ſquares, of a bitter and rather ſtyptic taſte. On hot coals it decrepitates, like muriat of ſoda; and it is ſcarcely ſoluble in water.

Lime-water decompoſes this ſalt, in the ſame manner as it does fluat of potaſh.

Sulphuric acid diſengages the acid with effervеſcence and the production of white ſtrong-ſmelling vapours, reſembling thoſe of muriatic acid.

This ſhort account ſhows, that fluat of ſoda is not better known than the fluat of potaſh.

Species XI. Carbonat of Potaſh.

The two perfect neutral ſalts, which remain to be examined, are combinations of the carbonic acid with fixed alkalis.

Theſe ſubſtances have never been ranked among neutral ſalts, though they are truly ſuch, as we ſhall ſhow.

By the name of carbonat of potaſh, we diſtinguiſh a neutral ſalt, produced by the ſaturated combination of the carbonic acid with potaſh. Some modern chemiſts diſtinguiſh it by the name of *mephitic tartar*, *aerated vegetable alkali*, &c. This ſaline ſubſtance was not known to be a neutral ſalt, but was always taken for a pure alkali, till the time of Dr. Black. It was formerly called *fixed ſalt of tartar*, becauſe it is obtained by the incineration of tartar of wine. It was conſidered as an alkali, becauſe it has ſome of the properties of thoſe ſalts; in fact, it gives a green tinge to the ſyrup of violets; but borax and ſeveral other ſalts have the ſame property; beſides which, it does not deſtroy or diminiſh the colour of violets, like potaſh. Borax likewiſe has an alkaline taſte. It was diſtinguiſhed from the alkali of ſoda, by the property it was ſaid to have of ſtrongly attracting the humidity of the air, and its being incapable of cryſtallization; thus moiſtened it was called *oil of tartar per deliquium** ; but theſe two properties depend on the ſalt of tartar not being perfectly neutralized, as it contains a certain quantity of potaſh not ſaturated with carbonic acid, by reaſon of which exceſs of alkali it is deliqueſcent. This ſalt is now obtained very cryſtallizable, and rather effloreſces than attracts the humidity of the air. M. de Chaulne, who has made many experiments relating to this ſubject, prepares the ſalt, by expoſing a ſolution of cauſtic potaſh, or potaſh combined with a little carbonic acid in a place filled with the carbonic acid gas; as for example, the upper part of a vat of beer in a ſtate of fermentation. The alkali becomes ſaturated with the carbonic acid, and cryſtallizes regularly in quadrangular priſms, terminated by very ſhort four-ſided pyramids.

The taſte of carbonat of potaſh is urinous, but much leſs ſtrong than that of the cauſtic vegetable alkali, as it may be employed in medicine in a doſe of ſeveral grains. This neutral ſalt melts readily in the fire, and quickly becomes alkalized; if it be diſtilled in a pneumato-chemical apparatus, its water of cryſtallization and its acid in an aeriform ſtate are obtained, and the potaſh remains fixed in an irregular maſs, together with a ſmall portion of the acid, which cannot but with the greateſt difficulty be expelled. According to the analyſis of Bergman, the carbonat of potaſh, ſaturated with acid, and in perfect cryſtals, which he calls *aerated vegetable alkali*, contains, in the centenary, twenty parts of acid, forty-eight of pure alkali, and thirty-two of water. But it muſt be obſerved, that the carbonats appear to be more particularly ſuſceptible of variation, with reſpect to the doſes of acid they may contain. However, as the ſalt we now ſpeak of never cryſtallizes regularly but when it is perfectly ſaturated, the calculation of Bergman may be eſteemed accurate[a].

Carbonat of potaſh, when well cryſtallized, is not altered in any reſpect by expoſure to air; its cryſtals remain tranſparent, and neither melt nor effloreſce. As it may be of great utility in many experiments, to have this ſalt ſufficiently pure, to poſſeſs this property of withſtanding the effects of the air, we think it neceſſary to obſerve, that it may be conveniently prepared by expoſure of a ſolution of very pure potaſh, completely free from the ſulphat of potaſh, which this ſalt uſually contains, to the carbonic acid in the upper part of fermenting veſſels; or ſtill better, by agitating it, and pouring it continually from one veſſel into another. We then allow the ſolution to remain in contact with the carbonic acid diſengaged during fermentation, till it depoſites cryſtals of the carbonat of potaſh [b].

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* Bohnius reports, that having evaporated *oil of tartar* ſlowly, by a gentle heat he obtained under a ſaline pellicle, fine cryſtals, which he preſerved for ſix years without alteration, though expoſed to different temperatures. (*Diſſert. Phyſico-Chim.* 1666.) M. Montet, a celebrated chemiſt of Montpelier, doubtleſs unacquainted with the diſcovery of Bohnius, likewiſe diſcovered a proceſs for cryſtallizing the fixed ſalt of tartar. *Memoirs of the Academy of Sciences*, 1764, page 576. *Note of the Author.*

This ſalt diſſolves in four parts of cold water, and requires rather leſs hot water for the ſame purpoſe [c]. During the time of ſolution, cold is produced. This laſt property, which diſtinguiſhes the neutral from the ſimple ſalts, is ſufficiently characteriſtic of the difference between carbonat of potaſh and the pure or cauſtic potaſh. It cryſtallizes by evaporation and cooling: if its ſolution be too concentrated, it takes the form of an irregular maſs, a circumſtance which often happens in laboratories.

Like potaſh, it may be uſed as a flux for vitrifiable earths, becauſe the action of the fire diſſipates the carbonic acid; if a mixture of ſand with this ſalt be ſtrongly heated in a crucible, a conſiderable efferveſcence will be obſerved at the inſtant of vitrification, occaſioned by the diſengagement of the aeriform acid, a phenomenon which proves that ſiliceous earth cannot combine with the alkali, while ſaturated with this acid; and that it is this which is diſengaged in the inſtant of vitreous combination. This efferveſcence is ſo conſtant, that it is aſſumed as a characteriſtic of ſiliceous earth by Bergman, in his treatiſe on the Blow-pipe, who directs its fuſion with the carbonat of potaſh, for the purpoſe of obſerving this character.

Alumine has no action on the carbonat of potaſh, which reduces this earth, by fuſion, into a vitreous frit, though rather more difficultly than the cauſtic potaſh. Barytes deprives this ſalt of the carbonic acid it contains.

Lime likewiſe decompoſes it, by virtue of its greater affinity than that of potaſh with the carbonic acid: if lime-water be poured into a ſolution of carbonat of potaſh, a ſalt ſcarcely ſoluble is formed, by the union of the lime with the carbonic acid, which falls down, and the pure or cauſtic alkali remains diſſolved in the fluid; this decompoſition is uſed in pharmacy to prepare the *lapis cauſticus*, which conſiſts of the fixed alkali, rendered cauſtic by means of lime. Modern diſcoveries have ſhown that the proceſs of Lemery, adopted in many pharmacopeias, is very defective. It conſiſted in mixing two pounds of crude alkali [*], with one pound of quicklime, to which ſixteen pounds of water were added; this being filtered and evaporated in a copper veſſel, afforded a reſidue, which was melted in a crucible, and poured out on a ſmooth ſtone. In this operation, an impure and ſcarcely cauſtic alkali, charged likewiſe with copper, is obtained.

Bucquet, aware of theſe inconveniencies, directs the proceſs to be made, in a more expenſive and leſs expeditious way, but with much more certainty in the procuring a very pure potaſh, ſo neceſſary to be had in chemical experiments. Two pounds of good quicklime is moiſtened with a ſmall quantity of water, to cauſe it to fall into powder; one pound of fixed ſalt of tartar is added, together with a ſufficient quantity of water to form a paſte; when the whole is grown cold, ſixteen pints of water are added, and the mixture is placed on a paper, ſupported by a piece of linen. About twelve pounds of a clear liquor paſs through, and the reſidue is waſhed with four pints of boiling water, to carry off the whole of the alkali. This liquor does not efferveſce with acids; but the beſt teſt of its perfect cauſticity is, its not occaſioning a cloud in lime-water, which it will do, if it contain the ſmalleſt quantity of carbonic acid. The liquid is not, however, ſufficiently pure to ſtand this teſt, and muſt be again treated with two additional pounds of quicklime, to bring it to that degree of perfection which is deſirable for nice experiments. If the alkali be obtained from this liquid, by evaporation in open veſſels, it ſeizes the carbonic acid contained in the atmoſphere; it muſt therefore be evaporated to dryneſs in a retort when the ſolid form is wanted. This tedious operation is not neceſſary in making the *lapis cauſticus*, which will anſwer its intention, provided it contain a ſufficient quantity of cauſtic alkali to corrode the ſkin; but as the accurate experiments of modern chemiſtry require the dry cauſtic potaſh in a ſtate of purity, it is proper to obſerve, that the evaporation of the cauſtic alkaline lixivium ought to be made in cloſed veſſels, and that this evaporation requires the fire to be carefully managed towards the end, on account of the great denſity the liquid acquires. The fixed alkali obtained by this proceſs ought to be exceedingly white, to make no efferveſcence with acids, and to produce no precipitation when added to lime-water.

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[*] Or *cendres gravélees*. Theſe are the aſhes afforded by the combuſtion of the marc or huſks of grapes, and the dregs of wine. They contain much vegetable alkali, or carbonat of potaſh, together with ſome ſulphat of potaſh. *Note of the Author*.

Magneſia produces no effect on carbonat of potaſh, becauſe the vegetable fixed alkali has a ſtronger affinity to carbonic acid than to this ſalino-terreſtrial ſubſtance.

The ſulphuric, nitric, muriatic, and fluoric acids, decompoſe carbonat of potaſh, by uniting with the fixed alkali, and ſeparating the carbonic acid, which is diſengaged with efferveſence. This acid, in the gaſeous ſtate, may be collected over water and mercury; it is known by the four following characters: it is heavier than the air of the atmoſphere, extinguiſhes flame, reddens turnſole, and precipitates lime-water.

The acid of borax does not ſeparate the carbonic acid from this ſalt in the cold, but very eaſily produces the effect when heated.

The neutral ſalts hitherto examined have no action on carbonat of potaſh. This ſalt is very abundantly found in nature: it exiſts ready formed in vegetables, and is obtained by the incineration of theſe organic bodies, as we ſhall more particularly deſcribe in our account of the vegetable kingdom. It is obtained more particularly from burned tartar, and is likewiſe prepared by the detonation of nitrat of potaſh.

The uſes of carbonat of potaſh in the arts are many; it is employed in medicine as a very active ſolvent; in obſtructions of the meſentery and the urinary paſſages, it is not adminiſtered but in ſmall doſes, together with ſome ſubſtance which may moderate its action.

Species XII. Carbonat of Soda.

This neutral ſalt, like the foregoing, was till lately conſidered as an alkali, though it is a combination of the mineral alkali with carbonic acid: it appears to be the ſalt known to the ancients by the name of *natrum*. It is commonly called *ſalt of ſoda*, becauſe it is obtained in a conſiderable degree of purity, and well cryſtallized by evaporating a lixivium of ſoda. The diſtinction made between the vegetable fixed alkali and the marine alkali, founded on the property of the latter to cryſtallize and fall into efflorescence, ariſes merely from its being ſaturated with carbonic acid in its ordinary ſtate.

The carbonat of ſoda has an alkaline taſte, and renders the ſyrup of violets green, though this does not alter its colour ſo much as the cauſtic ſoda does; its taſte is urinous, but neither ſo burning nor ſo cauſtic as that of the ſame alkali in a ſtate of purity.

This ſalt is commonly found purer than carbonat of potaſh, becauſe its property of cryſtallizing has long been known; this property, as we have before obſerved, is a general criterion to diſtinguiſh neutral from ſimple ſalts. It owes this property to its almoſt always containing the quantity of carbonic acid neceſſary for its ſaturation and cryſtallization.

This neutral ſalt haſtily cryſtallized, appears to be formed of rhomboidal laminæ, obliquely applied on each other, after the manner of tiles. When it is ſlowly cryſtallized, it takes the form of rhombic octahedrons, whoſe pyramids are truncated very near their baſe, or decahedral ſolids, with two acute and two obtuſe angles.

This ſalt is more fuſible than carbonat of potaſh, and is for that reaſon preferred by glaſs-makers; it loſes the greateſt part of its acid by the action of heat, but always retains a part. Bergman, by an accurate analyſis, found that one hundred parts of carbonat of ſoda, which he calls *aerated mineral alkali*, contain ſixteen parts of acid, twenty parts of pure alkali, and ſixty-four parts of water, ſo that ſoda requires a larger portion of carbonic acid for its ſaturation than potaſh, and retains twice the quantity of water; its more regular cryſtallization, and its property of efflореſcing, ſeem to depend on this portion of water.

Carbonat of ſoda is more ſoluble than carbonat of potaſh, as it requires only twice its weight of cold water, or half that quantity of boiling water, to hold it in ſolution. It cryſtallizes by cooling; but ſpontaneous evaporation affords more regular cryſtals. This ſalt expoſed to the air, readily falls into powder, by the loſs of its water of cryſtallization; it is not, however, altered by this effloreſcence, but recovers its original form by ſolution in water and cryſtallization.

The fuſion of vitrifiable earths is greatly facilitated by this ſalt, and the glaſs it forms is more durable than that into which the carbonat of potaſh enters; which is a ſecond reaſon for preferring it in the glaſs manufactories. The ſame diſengagement of the carbonic acid from this ſalt, when fuſed with ſand, as was obſerved to take place in carbonat of potaſh, is alſo found to take place with this. It has no more action on clay than the laſt mentioned ſalt.

Barytes, lime, and its aqueous ſolution, decompoſe carbonat of ſoda as they do that of potaſh, and diſengage the cauſtic mineral alkali. When a ſolution of this ſalt is added to lime-water, a precipitate falls down, which is not obſerved when the cauſtic is uſed. The cauſtic mineral alkali may be obtained for exact or minute chemical purpoſes by the ſame proceſs with this ſalt, as we have before directed to be made for the preparation of the *lapis cauſticus* with potaſh.

The carbonat of ſoda like that of potaſh is alſo decompoſed by the ſulphuric, nitric, and muriatic acids, and the carbonic acid may be collected over water or mercury.

This ſalt is found ready formed on the ſurface of the earth in Egypt, and elſewhere. It is likewiſe found in the aſhes of marine plants, but not ſaturated with acid. To render it perfectly neutral, it may be directly combined with the carbonic acid, either by agitating it over liquors in fermentation, or by receiving the carbonic acid diſengaged from chalk, by ſulphuric acid. It may likewiſe be prepared by pouring carbonic acid into a veſſel, the ſides of which have been moiſtened with a ſolution of ſoda. The veſſel is covered with a wet bladder, and at the end of a few hours the combination is effected. The bladder ſinks in the veſſel, on account of the vacuum which is formed in it, while the ſalt is depoſited in regular cryſtals on its ſides.

The carbonat of ſoda may be employed for the ſame uſes as the carbonat of potaſh; and as it is much more valuable in the manufactories of glaſs, ſoap, &c. an effectual method of obtaining from marine ſalt, would be a valuable acquiſition to ſociety. We have ſeen that litharge, propoſed by ſome chemiſts to produce this effect, does not decompoſe the ſalt; that Scheele has diſcovered a more evident decompoſition of the muriat of ſoda, by lime and iron, with the aſſiſtance of the contact of the atmoſphere, and the carbonic acid it contains. We ſee, that a proportion of this acid, greater than that which commonly exiſts in the atmoſphere, muſt favour this decompoſition, by acting upon the ſoda by its attraction

NOTES ON CHAPTER V.

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I. SULPHITE OF POTASH.

a Since the publication of theſe Elements, Fourcroy has more minutely inveſtigated the properties of the different ſulphites. This and the following note are taken from a tranſlation of his memoir in Mr. Nicholſon's valuable Journal.

Sulphureous acid gas was paſſed into a ſaturated ſolution of very pure carbonat of potaſh, until the effervescence ceaſed entirely. During this combination, a ſmall quantity of caloric was diſengaged, and the ſolution cryſtallized by cooling.

This ſalt is uſually white and tranſparent; ſometimes it is ſlightly yellow and ſemitranſparent, if its ſolution has been very concentrated, and the cryſtallization confuſed. Its taſte is penetrating and ſulphureous; its figure that of a rhomboidal plate; its cryſtallization often preſents ſmall needles diverging from a common centre.

When expoſed to a ſudden heat, it decrepitates, and loſes its water of cryſtallization; afterwards, by ignition, it emits ſome vapours of ſulphureous acid. At length a portion of ſulphur is ſeparated, and the reſidue is ſulphat of potaſh, with a ſlight exceſs of alkali.

By expoſure to air, it ſlightly effloreſces, becomes opake and hard, its penetrating ſulphureous taſte diſappears, and it acquires another which is acrid and bitter. In this ſtate it no longer effervefces with acids.

If this experiment be made in a cloſed apparatus with oxygen gas, it is found that the volume of the gas is diminiſhed, and that it is even totally abſorbed, when the quantity is properly regulated. We ſee, therefore, that the ſulphite of potaſh may be converted into ſulphat, by depriving it of a portion of its ſulphur by fire, or by introducing a quantity of oxygen at a low temperature.

The ſulphite of potaſh is ſoluble in a quantity of water nearly equal to its own maſs; and this ſolubility is increaſed by heat.

This ſalt is decompoſed by lime and barytes, as may be ſhown by pouring lime-water into a ſolution of ſulphite of potaſh. A white precipitate is afforded, which is the ſulphite of lime; and the potaſh remains diſengaged in the water.

The ſulphureous acid does not, therefore, follow the ſame laws of affinity as the ſulphuric acid, ſince this laſt adheres more ſtrongly to potaſh than to lime.

The alkalis do not change the nature of the ſulphite of potaſh.

Among the acids, ſome decompoſe the ſulphite of potaſh, by ſeparating the ſulphureous acid; others change its nature without driving off its acid, by affording a portion of oxygen, and converting it into ſulphuric acid. The firſt of theſe effects is produced by the ſulphuric, muriatic, phoſphoric, and fluoric acids; the ſecond is effected by the nitric and the oxygenated muriatic acids. The acids of borax and of carbon do not occaſion any change in the cold.

When the ſulphuric acid is poured on the ſulphite of potaſh, a rapid effervefcence takes place, with a crackling noiſe, at the ſame time that much caloric is diſengaged.

The nitric acid, on the contrrry, emits red vapours, mixed only with a ſmall quantity of ſulphureous acid; and the reſidue is compoſed of a mixture of the ſulphat and nitrat of potaſh.

The oxygenated muriatic acid mixed with the ſulphite of potaſh immediately loſes its ſmell, and the fluid is deprived of its ſulphureous taſte.

If the ſolution of the ſulphite of potaſh, and alſo that of the oxygenated muriatic acid, be both concentrated, cryſtals of the ſulphat of potaſh are formed immediately on the mixture.

Charcoal converts the ſulphite of potaſh into the ſulphure of potaſh. Salts with baſes of potaſh do not decompoſe this ſalt.

Thoſe with baſes of ſoda, except the borat and the carbonat, are decompoſed by the ſulphite of potaſh.

All the other ſalts, of which the acids are ſtronger than ſulphureous acid, are equally decompoſed by the ſulphite of potaſh.

The ſuperoxygenated nitrat and muriat of potaſh, when heated with the dry ſulphite of potaſh, take fire, and are changed into ſulphat.

Several metallic oxyds act upon this ſalt. Some are entirely reduced to the metallic ſtate, ſuch as the oxyds of gold, ſilver, and mercury; others are brought nearer to that ſtate, ſuch as thoſe of lead, iron, and manganeſe, at the maximum of oxygenation. There are others which change the nature of the ſulphite of potaſh in an oppoſite direction to that which takes place in the foregoing caſes, that is to ſay, which convert it into ſulphat, by depriving it of a certain quantity of ſulphur, with which they form ſulphurated oxyds, ſuch as the oxyds of arſenic and of iron ſlightly oxydated. But in order that this operation may ſucceed, it is neceſſary to boil theſe ſubſtances a long time in water, and afterwards to add to the ſolution an acid which occaſions a coloured precipitate, at the ſame time that ſulphurated hydrogen gas is emitted.

All the metallic ſolutions, except the carbonates, are decompoſed by the ſulphite of potaſh; and as moſt of the metallic ſulphites are inſoluble, different coloured precipitates are formed, according to the nature of the metal, and its ſtate of oxydation. See *Journal de l'Ecole Polytechnique*, p. 445.

II. SULPHITE OF SODA.

b This ſalt is white, and perfectly tranſparent; its figure a four ſided priſm, two of the ſides being very broad, and two narrow, terminating in dihedral pyramids. Its taſte is cool, and afterwards ſulphureous.

Its habitudes in the fire are abſolutely the ſame as thoſe of the ſulphite of potaſh; except only that it commences its operations by the aqueous fuſion.

By expoſure to the air it effloreſces, and is afterwards converted into ſulphat, but leſs ſpeedily than the ſulphite of potaſh.

It requires four parts of water for its ſolution; is more abundantly ſoluble in hot water; and readily cryſtallizes by cooling. Barytes, lime, and potaſh decompoſe the ſulphite of ſoda.

It is inſoluble in alcohol.

Salts with baſes of potaſh, except the carbonat, do not decompoſe this ſalt. The other genera decompoſe it, like the ſulphat of potaſh.

The metallic oxyds, and their ſolutions in acids, have the ſame effects with the ſulphite of ſoda as with that of potaſh.

It contains in the 100 parts, 18,8 of ſoda, 32,2 of acid, and 50 of water.

III. NITRAT OF POTASH.

a The nitrat of potaſh is found native in a great variety of ſituations. In India and Spain, it appears at certain ſeaſons of the year on the ſurface of particular ſoils. It has been found on the inſide of calcareous caverns in France and Germany. It exiſts irregularly cryſtallized in the calcareous ſtrata of Pulo, a cavity in the neighbourhood of Molfetta.

See *Kirwan's Mineralogy*, Vol. II. p. 25.; *Klaproth's Beiträge, erſter band, ſ.* 317.

Of late years, nitre has occupied much of the attention of the French chemiſts. Conſiderable light has been thrown on the theory of its formation, and ſeveral improvements ſuggeſted in the various proceſſes of its manufacture. The reſult of their inquiries and labours on this intereſting ſubject, are to be found in a memoir drawn up by Chaptal, and inſerted in the 20th volume of the *Annales de Chemie.*

A hundred parts in weight of nitrat of potaſh, conſiſt, according to Mr. Kirwar, of 41,2 of nitric acid, 46,15 of potaſh, and 12,83 of the water of compoſition. The acid, as has been fully proved, reſults from the combination of 7 parts of oxygen, with 3 of azote. The alkali is ſuppoſed to be derived immediately and entirely from the vegetable matter employed in the proceſs of nitrification; though there is ſome reaſon to ſuſpect, it may in part be formed by the developement and ſubſequent union of its elementary principles. We can be at no loſs to account for the origin of the water.

The principal circumſtances to which it is neceſſary to attend in the conſtruction of artificial nitre beds, are, firſt, the choice of materials. Theſe, as Fourcry remarks, are ſuch vegetable and animal bodies as are moſt ſuſceptible of decompoſition, with a proper admixture of calcareous earth. Though, in the vegetable kingdom, there be a conſiderable latitude of choice, yet experience has ſhown, that all vegetables are not equally ſuited for the production of nitre. In general, thoſe vegetables are to be preferred which are moſt eaſily decompoſed, and which ſeem to contain moſt of the elementary principles of that ſubſtance. Of this kind are ſome of the poiſonous plants, and plants of a ſtrong and fœtid odour, ſuch as hemlock, tobacco, lungwort, henbane, cabbage, hoarhound, nettles, &c. The extract of theſe plants is found, by keeping, to be covered with cryſtals of nitre. The cruciform and leguminous plants anſwer extremely well for the production of nitre. The dry and fibrous parts are of leaſt uſe.

Among animal ſubſtances, the ſoft are to be preferred to the hard, becauſe they are more readily decompoſed. Herbiverous are in general preferred to carniverous animals. Worms, inſects, and reptiles are ſaid to be capable of being reſolved almoſt entirely into nitre. Blood ſeems to be the animal fluid which affords the greateſt quantity of this ſubſtance. The dung of hens and pigeons has always been conſidered as extremely productive. That of oxen is ſaid to yield leſs than that of ſheep. Urine ought to be employed only towards the latter ſtage of the proceſs of nitrification, as it favours the production of muriat of ſoda. The purpoſe which theſe animal and vegetable ſubſtances ſerve in nitrification is now known. They all give out, during their decompoſition, a greater or leſs quantity of azote, which, uniting with the oxygen of the atmoſphere, forms the nitric acid. But the preſence of lime, or of ſome alkaline baſis, is neceſſary to fix this acid. When vegetable or animal bodies are mixed with ſiliceous or aluminous earths, little or no nitric is produced ; the acid which is ſaid to be formed being either exhaled into the air, or carried off by the water. The addition of an alkaline ſubſtance is proper only towards the end of the proceſs : if added ſooner, it retards the decompoſition of the organic ſubſtance.

The lighteſt and moſt porous calcareous ſubſtances are found to anſwer beſt. Their property of affording nitre is increaſed by their containing a quantity of iron : it is increaſed alſo by dividing them minutely, ſo as to increaſe as much as poſſible the extent of their ſurface. It ſeems to be for the ſame reaſon that calcareous ſubſtances which contain an admixture of ſiliceous or aluminous earth, or even of chaff, are more productive than the calcareous earths which are pure. It is not eaſy to determine nor to preſerve the juſt proportion between the earthy baſe and the putrefying principles ; it muſt be ſuch, however, that all the acid formed may be readily combined. Too great a proportion of earth is hurtful, not only by its occupying an uſeleſs ſpace, but alſo by retarding putrefaction. In general (Chaptal ſays), the proportion of calcareous earth may vary from one-fifth to one-tenth of the volume of the vegetables employed. Beſides ſerving as a baſe to fix the acid, do not calcareous ſubſtances diſpoſe the oxygen and the azote to unite, in conſequence of the *affinité diſpoſé?*

The oxygen gas combines with azote only in the moment of its diſengagement from animal or vegetable matters, and before it has aſſumed the gaſeous form. In this ſtate it has been not unaptly termed, *Naſcent* azotic gas. A high degree of temperature becomes, therefore, improper, becauſe it would cauſe the azote to aſſume the gaſeous form, and would conſequently prevent the formation of the acid. A very low temperature is equally injurious, becauſe, by retarding or putting an entire ſtop to the decompoſition, it prevents the diſengagement of azotic gas. Experience has ſhown, that the temperature fitteſt for the production of nitre lies between 75° and 90° of Fahrenheit. This temperature muſt reſult from the decompoſition of the animal and vegetable ſubſtances, and not be merely the effect of art. It is to be preſerved by excluding carefully currents of cold air, which would tend to carry off the heat.

An intenſe or ſtrong light ſeems to be very injurious to the production of nitre. Beſides the effect which it will undoubtedly have of volatilizing the azote, it may fairly be queſtioned, whether it will not alſo decompoſe the nitric acid. Saltpetremakers, aware of this pernicious tendency of too ſtrong light, have generally choſen a northern expoſure for their nitre beds. This expoſure has the additional advantage of preſerving a more equal temperature. Towards the latter ſtage of the decompoſition, it has been found uſeful to expoſe the putrifying matters to the light. At this period it ſeems to give new energy to the proceſs, and to promote greatly the production of nitre.

In order to produce the combination of the oxygen gas with the azote, it is neceſſary that theſe two ſubſtances ſhould remain for ſome time in contact with each other. All currents of air muſt, therefore, be unfavourable to the production of nitre ; and hence it is that we find ſaltpetremakers recommend, that the air ſhould be in a ſtate of abſolute reſt or ſtagnation. In order to increaſe the ſurface expoſed to the air, it is a common practice with ſome ſaltpetremakers to fix ſtakes of wood in various directions in the nitre beds. After the maſs has become dry and a little firm, theſe ſtakes are withdrawn, that the air may penetrate every part of the maſs, and come into contact with as large a ſurface as poſſible. The propriety of occaſionally renewing this air muſt be obvious to every one who reflects, that this is the ſource from which the oxygenous part of the nitre is derived. It becomes neceſſary alſo, particularly in the later periods of the proceſs, to ſtir the maſs, and expoſe every part of it to the action of the air. Great caution is required not to do this either too early or too often, as it is apt to retard putrefaction.

Either too great or too ſmall a degree of moiſture is equally unfavourable to the formation of nitre. In a hot and dry atmoſphere, the parts of vegetables and animals would be diſſipated without undergoing the proceſs of putrefaction. Too much moiſture, on the contrary, might not only retard the putrefaction, but might alſo carry off the acid after it had been formed. Great caution, therefore, is neceſſary in watering the nitre beds. The liquids moſt proper for this purpoſe are, the blood of animals, either by itſelf, or diluted in water, the water from dunghills, ſewers, &c. Theſe, beſides affording the neceſſary degree of moiſture, contain much vegetable and animal matter in a ſtate highly favourable to the production of nitre.

Such are the general principles on which nitre beds are conſtructed; but the particular ſteps of the proceſs vary in different countries. Theſe will be beſt underſtood by examples.

In Pruſſia, five meaſures of black vegetable earth, or the earth of ſubterranean caverns, are mixed with one meaſure of unlixiviated aſhes and ſome ſtraw. Theſe ſubſtances beat up with the water of dunghills or ſewers, are formed into walls or beds of 20 feet long, 6 or 7 feet high, and 3 feet broad at the baſe, declining to 2 at the top. Theſe beds are contained in ſhallow wooden caſes or moulds, and are covered with a thatch of ſtraw to protect them from the rain. They are moiſtened from time to time, and are fit for being lixiviated at the end of a year.

In Malta, they employ the moſt porous calcareous earth mixed with ſtraw, which has been lixiviated. Oblong triangular piles are formed of alternate layers, each half a foot in thickneſs, of this earth and dung. Theſe layers are terminated by a very thin layer of dung, applied looſely with the hand. The bed is occaſionally ſprinkled with mother water of ſaltpetre, urine, and water from dunghills. As ſoon as the ſurface becomes dry, it is turned down, and the bed moiſtened. This becomes fit for lixiviation at the end of three years. During the firſt year, the beds are every month ſprinkled over with the powder of ſlacked lime.

In Sweden, their beds are raiſed on bricks laid on the earth. On this baſis is placed a layer of mortar, compoſed of meadow turf, aſhes, lime, and the neceſſary quantity of mother water, or of urine. Over this is placed a layer of ſtraw; and theſe layers of ſtraw and mortar are continued alternately to the ſummit. The beds are defended from the rain, and moiſtened occaſionally with urine, ſtagnant water, &c. Theſe beds yield nitre at the end of a year, and laſt for ten years. The ſaltpetre is ſwept off every eight days; and after each ſweeping, the beds are moiſtened with weak mother water. The matter remaining at the end of ten years forms an excellent manure in the culture of hemp and flax.

In the canton of Appenzel, in Switzerland, they take advantage of the ſituation of their ſtables, on the rapid declivities of their mountains, to form very productive nitre beds. The upper ſide of theſe ſquare ſtables reſts on the mountain, while the lower is ſupported by ſtones or pillers of wood, raiſed two or three feet above the earth, according to the greater or leſs declivity. This leaves an interval open to the air between the floor of the ſtable and the mountain. In this place a ditch is dug of about three feet in depth. This ditch is filled with very porous earth, which imbibes the urine of the cattle. It is lixiviated every two or three years. The earthy reſidue is dried in the open air, and returned back into the ditch. In this manner they obtain about a thouſand pounds of ſaltpetre from an ordinary ſtable at each lixiviation.

The earthy part of nitre beds requires to be renewed more or leſs frequently according to the quantity of calcareous earth which it contains. No particular time can be ſpecified for the term of putrefaction, the periods of moiſtening the beds, or the time proper for turning them. The appearance of the beds, and the general principles already laid down, can only direct theſe particular ſteps, which muſt vary extremely according to circumſtances. The general marks by which a bed may be known to contain ſo much nitre as to make it worth working, are the efloreſcence and cracks on the ſurface in which no plants grow. If ſome of the particles of the bed be taſted, they will give a ſalt taſte, which will vary, however, according to the earthy or alkaline baſis, and may therefore be mild, acrid, or bitter. The bed muſt be afterwards examined to the depth of ſeveral inches, and in different places, in order to aſcertain whether the whole be nitrified. Another, but more troubleſome method, is, to lixiviate a ſmall quantity of the bed, a cubic foot, or yard, for inſtance, and from its produce to calculate the value of the whole.

[b] Concluſions preciſely ſimilar to thoſe in the text were deduced by Dr. Rutherford, from a variety of moſt accurate and ingenious experiments which he made on the decompoſition of nitre.

An account of theſe experiments was read to the Philoſophical (now the Royal) Society, in this place, ſo early as the year 1779.

It ſeems worthy of remark, that both Dr. Rutherford and Fourcroy had been anticipated for more than a century in ſome of their concluſions, by the now juſtly celebrated Mayow. I ſhall content myſelf with ſimply quoting the words of that great man.

" Quanquam autem ſpiritus nitri totaliter ab aere non procedit, credendum
" tamen eſt partem ejus aliquam ab aere oriundam eſſe. Quippe cum pars nitri
" aliqua ab aere ducatur, uti ſupra oſtenſum eſt: ſal autem fixum, quo nitrum
" ex parte conſtat, e terra oriatur; neceſſe eſt ut, quod reliquum eſt nitri, ſc.
" ſpiritus ejus acidus, igneuſque, ex aliqua ſaltem parte ab aere originem trahat.
" Quo autem pars ſpiritus nitri aerea clarius intelligatur, ſequentia breviter præ-
" mittenda ſunt.

" Primo concedendum eſſe arbitror, nonnihil, quicquid ſit, aereum, ad flam-
" mam quamcunque conflandam neceſſarium eſſe: id quod experimenta Boyliana
" extra dubium poſuerunt; utpote ex quibus conſtat, lucernam accenſam multo
" citius in vitro aere vacuo, quam in eodem aere repleto expirare; indicio mani-
" feſto, flammam, vitro incluſam, non tam a propria fuligine, uti nonnullis
" viſum eſt, ſuffocatam, quam pabulo aereo deſtitutam, interire: etenim cum in
" vitro vacuo plus ſpatii ſit pro fumo recipiendo, quam in vitro aere impleto, lu-
" cerna citius in hoc, quam in illo expiraret, ſi ejus extinctio a fumo procederet.
" Præterea materia quævis ſulphurea in vitro, ex quo aer exhauſtus eſt, collacata,
" neque carbone aut ferro ignitis, neque radiis ſolaribus, ſpeculi uſtorii ope col-

“ lectis, accendi poteſt: ut minime jam dubitandum ſit, quin particulæ quædam aereæ ad ignem excitandum omnino requiruntur: et utique noſtra fert opinio, eas in igne conflando præcipuas partes obtinere; flammæque formam ab iis, in motum perniciſſimum concitis, præcipue dependere; uti infra dicetur fuſius. At non eſt exiſtimandum, pabulum igneo-aereum ipſum aerem eſſe, ſed tantum partem ejus magis activam, ſubtilemque: quippe lucerna, vitro incluſa exſpirat, cum tamen copia aeris ſatis ampla in eodem continetur: neque enim credendum eſt, particulas aeris, quæ in vitro dicto extiterunt, per lucernæ deflagrationem annihilari; neque quidem diſſipari; cum eædem vitrum iſtoc pertranſire nequeant. Porro neque probabile eſt, particulas iſtas igneo-aereas nitrum quoddam perfectum eſſe, uti vulgaris fert opinio; etenim ſupra oſtenſum eſt, non ipſum nitrum totale, ſed tantum partem ejus aliquam in aere reſidere.

“ Secundo arbitrari fas ſit, particulas aeris igneas, ad flammam quamcunque ſuſtinendam neceſſarias, in ſal-nitro hoſpitari; partemque ejus magis activam, igneamque conſtituere: quippe annotare eſt, nitrum ſulphuri admixtum, in vitro aere vacuo, item ſubter aquas, ſatis prompte deflagare: uti ſequenti experimento, conſtabit; nempe pulvis pyrius minutiſſime tritus, cum aquæ tantillo in maſſam duriuſculum redigatur, qua tubulus quivis, cujus altera extremitas obturata eſt, denſe impleatur, materiam ſubinde cum bacillo fortiter impellendo; dein pulvis iſte pyrius in extremitate aperta accendatur, tubuluſque inverſus aquæ immergatur, ibidemque detineatur: ita pulvis pyrius ad totalem ſui abſumptionem ſubter aquas deflagrabit. Quinetiam pulvis iſte, modo prædicto diſpoſitus, in vitro, aere vacuo, ardebit: cum tamen ignes alii ob pabulum aeris ſubductum mox extinguuntur; indicio ſatis manifeſto, ſal nitrum particulas igneo-aereas, ad flammam conflandam requiſitas, in ſe continere, ita ut ad ejus deflagrationem, particulas igneas ab aere ſuppeditari, minime opus ſit.

“ Particulas inſuper igneo-aereas in nitro exiſtere liquet, quod flamma a nitro deflagrante excitata, a particulis igneo-aereis, ei innatis, motuque igneo confertim prorumpentibus, non vero a particulis ejus ſulphureis conflatur, etenim veriſimile eſt, nitrum particulas ſulphureas ſibi inſitas non habere: neque enim Clariſſimo D. Williſio aſſentire poſſum, qui in Tractatu de Fermentatione *ſulphur nitro copioſe ineſſe ſtatuit:* Cujus argumenta præcipua ſunt, ſtatim flammam concipiet; idemque in locis, ubi animalium excrementa ſulphurea ſunt, præſertim generatur. Verum tanti viri pace, nitrum purum putum particulis ſulphureis nequaquam impregnari putaverim: Etenim neque in ſpiritu nitri rectificato, neque in ſale alcali puro, quicquam ſulphuris combuſtibilis reperire eſt, et tamen ex iis utriuſque combinatis nitrum conflabitur. Quod vero nitrum, eo modo productum deflagrabit, non hoc a particulis ejus ſulphureis, quas nullas continet, ſed a particulis igneo-aereis ei inſitis, inque motum perniciſſimum concitis procedere credendum eſt. Quod ex ſequentibus magis adhuc manifeſtum erit.

“ Nempe advertere eſt, quod ad flammam quamcunque conflandam non tantum particulis ſulphureis, ſed inſuper igneo-aereis omnino opus ſit, uti jam oſtenſum eſt. Ad materiæ cujuſque ſulphureæ accenſionem, requiritur, ut particulæ igneo-aereæ ab aere, aut a nitro, ei prius admixto, ſuppeditentur: quæ cauſa eſt, quod ſulphur in loco aere vacuo flammam non concipiet, niſi nitrum ei admixtum fuerit. E contra vero ad nitri accenſionem non eſt opus, ut particulæ igneo-aereæ ab extra ſuggerantur; utpote quod in locis, a quibus aer præcluditur, ſatis prompte deflagrabit; verum ad ejus accenſionem omnino requiritur, ut materia aliqua ſulphurea ei admiſceatur. Etenim ſi nitrum in crucibulo ignito injiciatur, idem flammam non concipiet, ſi tamen materia quævis ſulphurea ei prius admixta fuerit, tunc nitrum crucibulo dicto injectum, mox in flammam prorumpet. Imo nitrum nulla ratione a flamma candelæ, aut radiis ſolaribus accendi poteſt, niſi ſulphur ei prius commixtum fuerit: et tamen idem nitrum carboni immiſſum facile accendetur; hoc autem propterea fit, quod particulæ ſulphureæ carbonis idem accendunt. Ex quibus certo conſtat, nitrum particulas ſulphureas ſibi inſitas, non habere; quæ cauſa eſt, quod ad illius deflagrationem particulas ſulphureas ab extra ſuppeditari neceſſe ſit. Unde ſequitur nitrum in flamma ab ipſo excitata, particulas tantum igneo-aereas, neutiquam vero ſulphureas, quibus prorſus deſtituitur, ſuppeditare. Et hinc eſt quod flamma nitri valde diverſa ſit ab ea, quæ a materia quavis ſulphurea deflagrante, excitatur; quippe materia ſulphurea particulis igneo-aeris ab aere ſuggeſtis, nitrum autem particulis igneo-aeris in ipſo confertim agglomeratis, agmineque denſiſſimo erumpentibus deflagrat: unde fit, quod flamma nitri maxime impetuoſa ſit; etenim formam ignis e particulis igneo-aereis præcipue dependere infra oſtendere conabor.

“Quod vero nitrum in locis ſulphure copioſo imbutis, præcipue naſcitur, ratio ex iis, quæ inferius dicentur, conſtabit.

“Ex quo tractatus hic ſcriptus eſt, Experimenta Boyliana, nuper edita, ad manus noſtras pervenerunt; quorum altero oſtenditur, quod, dum pulvis pyrius ope vitri uſtorii in vitro, aere vacuo, accenditur, flamma non uti alias per totam ejus molem propagetur; ſed tantum granula ea, quibus radii ſolis coacti incidunt, ignem concipiant. Ut videatur etiam ad pulveris pyrii accenſionem aeris acceſſum neceſſarium eſſe. Reſpondeo, licet pulvis iſte ope particularum igneo-aerearum ſibi inſitarum, in loco aere vacuo, et ſubter aquas deflagrabit, aeris tamen externi acceſſum pulveris iſtius accenſionem haud parum promovere; etenim annotandum eſt, aerem ob vim, qua pollet, elaſticam particulis Pulveris Pyrii ſulphureis proxime adjacere, et etiam fortiter premere: unde fit, quod, pulvere eo in aere libero ſemel accenſo, particulæ nitro-aereæ aeris, ad flammam continuandam nunquam non præſto ſint: cum tamen in pulvere pyrio particulæ igneo-aereæ nitri non niſi in granis ſingulis, particulis ſulphureis intime immiſcentur; neque verſus eaſdem accenſas feruntur: ita ut flamma pulveris iſtius in loco aere vacuo ob particularum igneo-nitroſarum ſeriem interruptam mox extinguatur. Verum quantum aeris elater ad ignem conflandum conducit, ex iis, quæ infra dicentur, magis conſtabit.

“Ex dictis aliquantenus conſtare arbitror, nitrum particulas igneo-aereas, ad flammam conſtituendam requiſitas, in ſe continere. Quapropter cum nitri pars aliqua ab aere oriatur, et particulæ aeris igneæ in eodem exiſtant; ſtatuendum eſſe videtur, *partem nitri aeream nihil aliud quam particulas ejus igneo-aereas eſſe.*

“Jam vero cum pars nitri aerea in ſpiritu ejus acido exiſtat, non vero in ſale fixo, quod reliquam nitri partem conſtituit, uti ſupra oſtendimus; concludere licet, *Particulas Igneo-aereas Nitri*, quæ cum parte ejus aerea idem ſunt, *in ſpiritu nitri reconditas eſſe, partemque ejus aeream* conſtituere.

“Nempe veriſimile eſt, ſpiritum nitri quid compoſitum eſſe; illiuſque particulas alias flexiles, humidas, indoliſque craſſioris eſſe; quæ a materia terreſtri procedere videntur; uti infra oſtendere conabor; particulas vero alias rigidas, ſiccas, maximeque ſubtiles, agiles, æthereaſque, et revera igneas eſſe, que tamen

"particularum ſalinarum, in ſtatu fluido, humidoque exiſtentium, conſortio obvo-"lutæ, ad motum igneum ineundum ineptæ ſunt; atque has demum ab aere "proſapiam ducere.

"Circa partem ergo ſpiritus nitroſi Aeream ſtatuimus, eam nihil aliud eſſe, "quam particulas igneo-aereas, quæ ad flammam quamcunque conflandam omni-"no neceſſariæ ſunt. Quocirca particulas iſtas igneas, aerique communes, *parti-"culas nitro-aereas*, ſive *ſpiritum nitro-aereum* in futurum nuncupare liceat."

[c] Nitre, during the firſt and ſecond boilings, generally loſes about 30 per cent. of its weight. It becomes, therefore, an object of ſome importance to poſſeſs a ſure and eaſy teſt by which we may judge of the proportion of pure nitre which any given quantity of crude may contain. But this ſubject, apparently ſo eaſy, is not without its difficulties.

As the ſalts which form a part of crude nitre vary greatly in the degree of their ſolubility in water, it has been uſual to ſeparate them by cryſtallization, according to the method deſcribed by Fourcroy. This method of judging of the degree of purity of crude nitre is not only tedious, but inaccurate; for the laſt portions of the nitre adhere ſo ſtrongly to the alkaline and earthy muriats, as to render the complete ſeparation almoſt impoſſible.

Morveau propoſed to employ a chemical re-agent as a teſt of the purity of this ſalt. His proceſs conſiſts in pouring as much alcohol on 100 drachms of dried crude nitre, as is ſufficient to diſſolve the nitrat and muriat of lime. The ſalt remaining is diſſolved in 3 pounds of water; and to this is added a ſolution of nitrat of lead. The muriatic ſalts and the nitrat of lead mutually exchange baſes; and the muriat of lead which is formed, is eaſily ſeparated by ablution and filtration. This proceſs, however, has not been found to anſwer; for the nitrat of potaſh and muriat of ſoda are not abſolutely inſoluble in alcohol; and the quantity of muriat of lead obtained from different portions of the ſame crude nitre varies from circumſtances which it is difficult to diſcover.

Baumé propoſed to ſubſtitute the acetite in place of the nitrat of lead. But there is in this laſt alſo a ſource of fallacy. Solutions of the acetite of lead and nitre have a reciprocal action on each other. When they are mixed together, a precipitate is formed, which adds conſiderably to the weight of the muriat of lead. This precipitate is, indeed, eaſily ſoluble in water, and may by this means be ſeparated from the muriat of lead. See *Journ. de Phyſ.* Tom. XLII. p. 433.

Another teſt recommended by Riffaut-des-Etre is the employment of a ſaturated ſolution of nitre in water; experience having ſhown, that water, after having been ſaturated with nitre, was ſtill capable of diſſolving additions of other neutral ſalts. This teſt, though extremely ingenious, and eaſy in its application, is liable to ſeveral inaccuracies; for if muriat of ſoda be added to a ſaturated ſolution of nitrat of potaſh, the ſolution will become capable of diſſolving an additional quantity of nitre. This quantity, however, does not ſeem to be in proportion to the muriat of ſoda. The degree of heat employed to dry the nitre to be tried will alſo produce variations in the reſult; for when the earthy ſalts which are mixed with, and which render the nitre impure, retain the water of their cryſtallization, they occaſion a precipitation rather than a freſh ſolution of that ſalt. Beſides, it is neceſſary, for the accuracy of this trial, that the water of ſolution be kept for ſome hours preciſely at the ſame degree of temperature, as nitre is more ſoluble in warm than in cold water. See *Ann. de Chem.* Tom. XI. p. 125.

Yet, even with theſe imperfections, this teſt ſeems to be the moſt accurate which has been diſcovered. Morveau gives the following account of the manner in which it is to be uſed.

Small pieces are to be taken from different parts of the ſaltpetre to be tried, and bruiſed together in an earthen veſſel, ſo as to form a homogeneous maſs. The teſt liquor is prepared by diſſolving as much purified nitre in water as it will diſſolve; the temperature of which has been raiſed to the boiling point. About a choppin (French meaſure, or 25,230 cubic inches), of this ſolution is to be poured on 13 ounces of the bruiſed ſalt, and the mixture well ſtirred for 15 minutes with a wooden or glaſs ſpatula. The ſalt is allowed to depoſit, and the liquor is then to be paſſed through a filtre, in order to detain any particles of the ſalt which may be floating in it. Half the former quantity of the ſolution is again to be added to the ſalt, and the mixture ſtirred for 15 minutes as before. The whole is now to be poured into a large glaſs funnel, and filtered through paper. When properly drained, the filtre is to be taken out with caution, and laid on a double leaf of gray paper. The ſalt is ſpread as equally as poſſible, and the paper laid to dry on a bed or layer of ſome abſorbent ſubſtance, ſuch as potaſhes, lime, tuffa, or plaſter. When the ſalt becomes ſo dry as to ſeparate eaſily from the filtre, it is put into a glaſs veſſel, and expoſed to the heat of a ſand bath till it ceaſes to adhere to the veſſel, or to the ſpatula with which it is ſtirred. By making the neceſſary allowances for the imperfections, which ſeem to be inſeparable from this proceſs, we can in this manner aſcertain pretty exactly, the proportion of pure nitre which any quantity of crude may contain. See *Guyton Ann. de Chem.* Sept. 1797, p. 225.

In refining the crude ſaltpetre at the public works in Paris, it was conſtantly found, that there was a difference between the quantity of pure nitre indicated by the teſt, and that actually obtained. This difference was far from being fixed; but, at a medium, it did not ſeem to be leſs than 5 parts in the 100. Lavoſier was employed by the Government to diſcover the cauſe of this deficiency, and, if poſſible, to point out the beſt method of obviating it. In reflecting upon this ſubject it occurred to him, that this loſs was probably occaſioned by the evaporation of a portion of the nitre during the various boilings it is made to undergo in the proceſſes of refining. The diſſipation of nitre by heat, was a fact which had been mentioned by Wallerius, and which had given much trouble to Mr. Kirwan in his uſeful experiments on the proportions of the conſtituent parts of ſaline bodies. The conjecture of Lavoiſier was ſoon verified by experiment. Five pounds of nitre diſſolved in river water were boiled for 24 hours, care being taken from time to time to replace the water carried off by evaporation. Only 4 pounds 8 ounces 3 gros 19 grains remained; ſo that 7 ounces 4 gros 53 grains had been diſſipated during the evaporation. The quantity which had diſappeared amounts, therefore, to 9 pounds 7 ounces 6 gros in the quintal. This loſs of nitre was found to be much greater in a ſtrong than in a weak ſolution of nitre. In order to avoid this loſs, Lavoiſier propoſes to purify the crude nitre, by pouring on it from 25 to 30 per cent. of cold water, according to the quality of the nitre, and the quantity of mother water which it may have contained. The mixture is to be ſtirred with rakes, till the nitre is properly waſhed, when the water is to be drained off. This firſt waſhing will carry off all the mother water, and a great part of the muriat of ſoda. What remains of this ſalt is to be carried off by a ſecond waſhing, in 35, 40, or 45 per cent. of water. By this ſimple and unexpenſive proceſs, Lavoiſier ſays, that 55 pounds of refined nitre may be obtained from 70 of crude, without any loſs, and in a ſtate ſufficiently pure for all the purpoſes of the arts, perhaps even for the fabrication of ſome kinds of gunpowder. See *Lavoſier Ann. de Chem.* Tom. XV. p. 225. Tom. XVI. p. 1.

Chaptal has given the following account of the proceſs which is now followed in the purification of nitre, in the 21ſt volume of the *Annales de Chemie.*

The nitre is firſt pounded, and put into tubs in quantities of 500 or 600 pounds, Twenty per cent. of water is poured into each tub. The mixture is well ſtirred, and left to digeſt for 6 or 7 hours, during which time the water acquires the denſity of between 25 and 35 degrees. This water is now poured off, and 10 per cent. of freſh water added, which is ſuffered to remain only for one hour. Five per cent. of water is now to be poured on, and immediately drawn off as ſoon as it has been ſtirred.

The nitre, when properly drained, is thrown into a boiler, containing 50 per cent. of boiling water. The ſolution will mark between 66 and 68 degrees of the hydrometer. The ſolution is next poured into a veſſel to cryſtallize, where, in the courſe of from 4 to 6 hours it depoſites about two-thirds of the original quantity of nitre. As it is of conſequence in the ſubſequent drying that the cryſtals ſhould be in ſmall needles, it becomes neceſſary to ſtir the ſolution during the whole time of the depoſition. The cryſtals formed are removed with a ſkimmer, and thrown into baſkets to drain, and the water which paſſes through is carefully collected. The ſaltpetre is afterwards put into wooden veſſels with double bottoms, formed in the ſhape of mill hoppers. The upper bottom, which is raiſed about two inches above the other, is perforated with a number of ſmall holes, through which the water paſſes to the lower bottom, from which it is diſcharged by a ſingle opening. The ſaltpetre is waſhed in theſe veſſels with 5 per cent. of water; and this water is afterwards employed in the ſolution of the ſalt. This ſaltpetre, well drained and expoſed for ſome hours to the air upon drying tables, may be uſed for the manufacture of gunpowder.

This ſalt may be dried more quickly by a ſtove, or by putting it in a flat metallic veſſel. For this purpoſe, it may be put into the veſſel to the depth of 5 or 6 inches, and heated to about 135° of Fahrenheit. By ſtirring it in this ſituation for two or three hours, it loſes its regular form, and puts on the appearance of a fine dry ſand. This degree of dryneſs, however, is not neceſſary when the gunpowder is made by pounding.

Two ſaline liquors remain after theſe operations. 1*ſt*, The waters from waſhing; and, 2*dly*, Thoſe from the cryſtalling veſſels. The quantity of water employed in the three different waſhings, amounts to 35 per cent. of the weight of of the crude ſaltpetre. It is employed on the principle, that cold water diſſolves the muriat of ſoda, and the earthy nitrats and muriats, together with the colouring principle, but ſcarcely attacks the nitrat of potaſh. The water from theſe three waſhings, therefore, will contain the muriat of ſoda, the earthy ſalts, the colouring principle, with a ſmall quantity of the nitrat of potaſh. The water of the cryſtallizing veſſels contains a portion of the muriat of ſoda, the earthy ſalts which eſcaped the waſhing, and a quantity of nitrat of potaſh, more conſiderable than that contained in the waters from waſhing. The water which is employed to waſh the cryſtals, contains only a ſmall quantity of the nitrat of potaſh.

Theſe waters are, therefore, very different in their nature. The waters from the waſhings form a true mother water. They are to be collected in veſſels, and treated with potaſh by the known proceſſes. They are evaporated to 66 degrees, and the muriat of ſoda taken out as it is formed. This ſolution is ſaturated with 2 or 3 per cent. of potaſh, then ſuffered to ſettle, and afterwards decanted into cryſtallizing veſſels, where 20 per cent. of water is to be added, to keep the whole of the muriat of ſoda ſuſpended.

The waters which are thus obtained from the cryſtallization of the ſalts contained in the mother waters may be mixed with the waters of the firſt cryſtallization. From theſe the muriat of ſoda may be ſeparated by ſimple evaporation; and the nitrat of potaſh, which they hold in ſolution, may be afterwards obtained by cooling.

V. OXYGENATED MURIAT OF POTASH. *

a During the combination of the oxygenated muriatic acid with potaſh, caloric is given out. The ſalt which is formed appears in quadrangular plates, or needle-like cryſtals. It requires 17 parts of water, at the temperature of 60, to diſſolve one part of this ſalt; while five parts of boiling water are ſufficient to diſſolve two parts of it. Repeated ſolutions do not ſeem to injure its detonating property.

Expoſure to light during the courſe of 12 months appeared to produce no change on this ſalt, either in a ſolid or diſſolved ſtate, as no gas had been diſengaged; and at the end of that period it detonated as ſtrongly as before.

Heat deprives it of its water of cryſtallization, and diſengages from it a great quantity of oxygen gas. Nearly one half of the weight of the ſalt may be obtained if the heat be intenſe.

The nitric and muriatic acids diſengage the oxygenated muriatic acid from potaſh. On putting a little of the ſalt into ſulphuric acid, a violent exploſion with flame is produced, and an elaſtic fluid diſengaged, which has the ſmell of nitrous gas.

Violent exploſion with flame was produced by rubbing half a grain of this ſalt with the ſame weight of phoſphorus. By adding ſome ſulphuric acid the mixture was inflamed.

A ſmart ſtroke on two grains of this ſalt with one of charcoal cauſed a vivid flame, but not a very loud report.

By rubbing a grain of it with half a grain of ſulphur, a very loud report, attended with flame, and a ſtrong ſmell of ſulphureous acid, was produced.

Loud exploſion and flame were likewiſe perceived, on rubbing a grain of it with equal weights of the ſulphures of potaſh or mercury.

Very ſlight friction exploded a grain of this ſalt with half a grain of the ſulphure of arſenic.

If a grain of refined ſugar be rubbed with two grains of the ſalt, they give a number of ſucceſſive reports.

Spermaceti oil, olive oil, and the eſſential oils of roſemary, juniper, cloves, carroway, aniſe-ſeed, cinnamon, nutmeg, mint, amber, and the eſſence of lemons, all detonate with this ſalt, and the mixtures take fire on the addition of the ſulphuric acid. Spirit of turpentine, camphor and roſin likewiſe produced exploſions on being rubbed with it. Little detonation, however, proceeded from

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* *The reference to this note is omitted in page* 462.

rubbing it with gumarabic and indigo; and Chaptal ſays, there is none with Pruſſian blue.

It is ſingular, that the nitric acid did not at all affect many of theſe mixtures which were inflamed by the ſulphuric. For more particular information on this ſubject, ſee *Hoyle, Mancheſter Memoirs*, Vol. V. Part I. p. 221.

According to Fourcroy and Vauquelin, the exploſions increaſe in violence in proportion to the rapidity of the friction, or force of the preſſure applied. The ſame effects, but more ſtrongly, are produced, by ſtriking the mixtures on an anvil as by rubbing them together.

Metallic arſenic detonated very ſtrongly with the oxygenated muriat of potaſh. The ſulphure of iron by triture inflamed rapidly with it, but did not cauſe any exploſion.

If the mixtures be wrapped up in double paper before they are ſtruck with the hammer, the exploſion produced is more violent. They add, that gunpowder detonated likewiſe by a violent blow.

The electric ſpark, like concuſſion, alſo cauſed the mixtures to detonate.

It would ſeem, from the experiments of Berthollet, that the acid in combination with the potaſh contains a greater quantity of oxygen than is contained in an equal quantity of uncombined acid. When the oxygenated muriatic acid, therefore, combines with potaſh, he conceives, that a portion of the acid is deprived of the oxygen, and forms ordinary muriat of potaſh; while the other portion of the acid, uniting itſelf with its oxygen, forms the oxygenated muriat of potaſh. Berthollet propoſes to extract oxygen gas from oxygenated muriat of potaſh, as it is obtained from this ſubſtance more readily, in greater quantity, and of a higher degree of purity, than from any other ſubſtance.

Oxygenated muriat of ſoda is deliqueſcent, according to Berthollet. In its other properties it reſembles the oxygenated muriat of potaſh. See *Fourcroy, Mem. de l'Acad*, 1788, p. 369; *Fourcroy & Vauquelin, Annal. de Chemie*, Tom. XXI. p. 235.; *Nichol. Journ.* Vol. I. p. 168.; *Berthollet, Jour. de Phyſ.* Tom. XXXIII. p. 217.

VI. MURIAT OF SODA.

a There are two varieties of ſal gem, the *lamellar* and *fibrous.* The latter is found only in amorphous maſſes. It is the lamellar which forms the large ſtrata of ſal gem. Theſe ſtrata vary greatly in their thickneſs. They are generally ſeparated from each other by a layer of clay. The colour of the ſal gem depends on ſome adventitious ſubſtance. The red colour has been ſuppoſed to be derived from iron, the violet from a ſmall portion of the muriat of mangaueſe, and the green from copper. Beſides, an admixture of clay, ſal gem often contains muriat of magneſia, and the muriat and ſulphat of lime.

The quantity of ſalt contained in ſea water varies greatly in different climates. At a medium, however, it is ſaid to be about one thirtieth of the weight of the water.

Some of the ſalt ſprings contain more, and others leſs ſalt than ſea water. In ſome places the water of theſe ſprings has been ſaid to contain one third, and often one fourth of its own weight of ſalt.

See *Watſon's Chemical Eſſays*, Vol. II. p. 33.

Kirwan's Mineralogy, Vol. II. p. 31; *Haſſenfratz Ann. de Chem.* Tom. XI. p. 65; *Nicolas Ann. de Chem.* Tom. XX. p. 78.

[b] The ſalt, formed by ſpontaneous evaporation, is uſually called *bay ſalt*. The ſalt which is obtained by ſlow evaporation, is alſo purer than that which is formed by quick boiling. The Dutch ſalt, in ſo great repute for the ſalting of fiſh, is prepared with a very gentle fire. They add a quantity of *ſour whey* to their brine before evaporation. The action of this ſubſtance does not ſeem to be well underſtood, though it is ſaid to conduce to the purity of the ſalt, and to favour the production of large cryſtals. The ſalt obtained by quick evaporation always contains more or leſs of the muriat of lime and ſulphat of ſoda.

[c] Scheele had obſerved, that by expoſing a mixture of two parts of the ſolution of ſulphat of magneſia, and one of the muriat of ſoda, to the temperature of freezing, ſulphat of ſoda was formed. More lately, Gren remarked, that a ſimilar effect is produced in ſea water expoſed to a low temperature, ſulphat of ſoda being formed in it by the double decompoſition of its muriat of ſoda and ſulphat of magneſia. It is remarkable, however, that an increaſe of temperature will not reproduce the muriat of ſoda, nor reſtore the ſalts to their former ſtate. From theſe facts, all muſt perceive the diſadvantage which will ariſe from concentrating ſea water by freezing, and the propriety of Gren's important plan of ſeparating the deliqueſcent ſalts before evaporation, in the art of ſalt making, by chemical affinity.

With this view he directs the addition of ſulphat of ſoda to waters, containing only the muriats of lime and ſoda, and of lime to thoſe which contain the muriat of magneſia and ſulphat of ſoda. In the latter inſtance, muriat of lime is firſt formed, which afterwards decompoſes the ſulphat of ſoda by double affinity.

Where the muriat and ſulphat of magneſia are preſent without the ſulphat of ſoda, or where the waters contain only the muriats of lime and magneſia, lime and ſulphat of ſoda ſhould be added at the ſame time.

But if the water contains the ſulphat and muriat of magneſia, together with the ſulphat of ſoda, lime alone will be neceſſary, unleſs the quantity of ſulphat of ſoda be inſufficient, in which caſe ſome of it muſt alſo be added.

In any of theſe proceſſes, the muriat of ſoda will be obtained pure, as the ſulphat of lime, the only other ſalt formed, ſeparates in the form of *ſchlot*.

Many advantages are thus gained. The bitter taſte of common ſalt, occaſioned by the preſence of the ſulphats of ſoda, and magneſia, is prevented; no mother water is formed, and pure muriat of ſoda alone is obtained on evaporating the fluid. Much expenditure of time and fuel is ſaved in the proceſſes of evaporation, and trying the ſalts, and a pure, not deliqueſcent, ſalt is obtained, capable of reſiſting the impreſſion of the air, and of being tranſported without loſs.

The principal objection to theſe proceſſes may ariſe from the neceſſity of purchaſing the ſulphat of ſoda; but the ſea water will itſelf in general produce it when brought to a temperature below zero; and for this purpoſe it will only be neceſſary to collect a quantity in the baſons, to be expoſed to the cold during the winter. We might from this water alſo obtain the ſulphats of ſoda and magneſia by adding the ſulphat of iron.

It will even be found advantageous to purify waters by theſe means, which do not contain ſulphat of magneſia, as the moſt unproductive waters will not require more than from fifty to ſeventy-five pounds of ſulphat of ſoda to produce thirty quintals of muriat of ſoda.

In following this method it will only be neceſſary to aſcertain the component parts of the fluid employed previous to aſcertaining what ſubſtances ſhould be added. Direct experiment will eaſily point out the quantities which may enſure the moſt perfect ſucceſs. *Vid. Ann. de Chem.* Tom. XXIV. p. 121.

[d] Lord Dundonald propoſes, in the purification of muriat of ſoda, to take advantage of the fact, that water, ſaturated with one ſalt, will yet diſſolve a portion of another ſalt. The proceſs which he recommends is as follows: Take a conical veſſel, having a hole in the ſmall end, which is to be undermoſt, and place it, filled with common ſalt, in a moderate heat: Saturate a portion of water with this ſalt, and pour the ſolution, boiling hot, on the ſalt in the conical veſſel. The boiling water will not diſſolve any of the common ſalt, but will diſſolve the bitter earthy ſalt which it contains. When the ſolution ceaſes to drop out of the hole at the bottom of the veſſel, the ſame proceſs is to be repeated by means of freſh portions of the ſame parcel of ſalt, already partly purified, till it be brought to the degree of purity required. Lord Dundonald reckons that three ſuch waſhings make the common ſalt of this country purer than any foreign ſalt; that each waſhing makes it $4\frac{1}{2}$ times purer than before; ſo that (diſregarding fractions) after the ſecond waſhing it will be 20 times, after the third 91 times, after the fourth 410 times, and, after the fifth, 1845 times purer than at the firſt.

A proceſs founded on the ſame principle is followed at Mount Morot in France. The water from the waſhing of the common ſalt is carefully preſerved, and the ſulphat of ſoda which it contains extracted by a new cryſtallization. See *Dundonald, Edin. Phil. Tranſ.* Vol. I. p. 19.

VII. BORAT OF SODA.

When two pieces of this ſalt are rubbed on each other in the dark, they emit ſtrong flaſhes of light. See *Nicholſon's Journal*, Vol. II. p. 28.

XI. CARBONAT OF POTASH.

[a] Pelletier, from his experiments on the carbonat of potaſh infers, that 100 parts of it conſiſt of 43 of carbonic acid, 17 of water, and 48 of pure alkali.

[b] Vegetable alkali often contains a ſmall quantity of ſiliceous earth, which it is difficult to ſeparate from it. Pelletier obſerved, that a white precipitate was formed during the combination of the carbonic acid with the alkali. This precipitate proved to be ſilex. He propoſes to combine potaſh with carbonic acid, in order to free it from its ſilex.

[c] During its ſolution in warm water, a portion of the carbonic acid is diſengaged under the gaſeous form. The acid which remains is inſufficient to ſaturate the alkali. See *Pelletier Annal. de Chem.* Tom. XV. p. 23.

END OF VOL. I.